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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXX.—*The Absolute Wave-length of Light;* by LOUIS BELL. Part II.

[Continued from page 282.]

THIS continuation of my previous paper contains the angular measurements and the details of the measurement and calibration of the gratings, together with the final results. In addition I have endeavored to point out the probable sources of error in some recent determinations of absolute wave-length.

Angular Measurements.

In my former paper (this Journal, March, 1887) the work with glass gratings was described in detail, so that it will only be necessary to summarize it here.

Grating I was used during October and November, 1886, and forty-eight series of observations were obtained as follows, each series consisting of three to seven observations.

Date.	Number of series.	Angle.
Oct. 19,	1	45° 1′ 47″·2
20,	1	45 1 48 ·4
22,	2	45 1 48 ·2
23,	1	45 1 49 ·8
26,	4	45 1 49 ·3
27,	3	45 1 48 ·2
31,	1	45 1 50 ·1

Date.	Number of series.	Angle.
Nov. 3,	1	45° 1′ 48″·6
4,	3	45 1 47 ·4
5,	2	45 1 47 ·9
10,	4	45 1 47 ·8
11,	6	45 1 49 ·7
16,	8	45 1 48 ·2
17,	5	45 1 47 ·5
20,	6	45 1 47 ·5

Grating I was used at an average temperature of very nearly 20°, to which all observations were reduced. The average barometric height was 761^{mm}, so that no correction was required for this cause. Weighting and combining the above observations the final value is

$$\varphi = 45^\circ\ 1'\ 48''{\cdot}24 \pm 0''{\cdot}11,$$

corresponding to the spectrum of the third order.

The resulting probable error in wave-length is about one part in a million.

Grating II was used in March, 1887, at an average temperature of very nearly 20° and an average pressure of 760^{mm}. Thirty-six series of observations were obtained in the fourth order, as follows:

Date.	Number of series.	Angle.
Mar. 6,	2	42° 5′ 1″·2
10,	1	42 4 58 ·6
11,	7	42 5 1 ·4
15,	1	42 5 4 ·0
16,	6	42 4 57 ·8
17,	6	42 4 58 ·5
18,	7	42 4 59 ·1
23,	6	42 4 58 ·3

Combining and weighting, the mean value is:

$$\varphi = 42^\circ\ 4'\ 59''{\cdot}28 \pm 0''{\cdot}2.$$

The probable error is equivalent to about one part in six hundred thousand in the wave-length.

Both the glass gratings were used exclusively for the line D_1, which was on the whole most convenient for measurement, D_2 being rejected by reason of the troublesome atmospheric lines. The relative wave-lengths of a very large number of lines have been so exactly determined by Prof. Rowland that any one of them would have given results equally valuable, and in the subsequent work with gratings III and IV, two of these standard lines were employed.

In this second part of the investigation, the gratings as before

mentioned were used on the large spectrometer in which the telescopes were kept at a fixed angle and the grating was turned. This method is, of course, applicable only to very solid instruments in which the angle can readily be kept constant, and it should be further noted that it also requires the use of very perfect gratings, since the grating is used asymmetrically. As a result of this the spectra on the two sides differ in dispersion, and if the ruling is irregular either in spacing or in contour of the individual lines, may differ quite widely in focal length, definition and illumination. After critical examination gratings III and IV appeared to be so nearly perfect in ruling, as to be quite secure from the dangers of the method. The method has moreover the distinct advantage of enabling the angle of deviation to be varied within certain narrow limits. Hence it becomes possible so to arrange the apparatus as to give to some convenient line a double reflection that shall be an exact submultiple of 360°. This once accomplished it becomes an easy matter completely to eliminate the errors of the divided circle and obtain a value of $n\varphi$, dependent only on the micrometer constants, which in turn may be themselves almost eliminated. To be sure, this method practically confined observations to the spectra of a given order and limits the choice of lines for measurement, but the first objection does not apply to gratings of which the ruling is very nearly perfect, and since the relative wave-lengths of a large number of lines are known with very great exactness, measurements of the absolute wave-length are quite comparable even if made on different lines.

As regards the constancy of the angle between the collimator and observing telescope there was every reason to expect entire permanence throughout the experiments, and observation soon justified this expectation. The telescopes were firmly secured at both ends to one and the same casting, which in turn was firmly bedded in a brick pier. In addition the size of the apparatus was such that a variation of even 1″ in the angle was quite improbable. The angle measured in the ordinary way with a collimating eye-piece could be determined to 1″ of arc, exclusive of errors of graduation in the circle. At first there appeared to be distinct variations in the angle as determined at the beginning of each series of observations, reaching sometimes more than 10″. It soon appeared however that when the same part of the circle was used the angle between the telescope was sensibly the same and the apparent variations were then traced to a periodic error in the divided circle, which by the method of repetition was completely eliminated from the measurements of angles of deviation and only appeared in the determinations of θ. This error was finally eliminated by measuring θ in various portions of the circle.

The method of determining φ was as follows: The instrument being adjusted by the ordinary methods, a suitable line was selected for measurement and then the angle θ was slightly increased or diminished until by measurement of a double deflection $n\varphi$ was found to be very close indeed to 360°. Then a double deflection was carefully measured and if time permitted several times repeated, an observer always being at the eye-piece to see that the line should not move from the cross hairs while the micrometers were being read. Then, clamping the main circle, the grating holder was turned through 2φ until the line was very closely upon the cross hairs, any slight readjustments made necessary by this disturbance of the instrument were made, and the process was repeated. In this way the initial line of the circle was finally reached and a value of $n\varphi$ obtained which depended only on the algebraical sum of the micrometer readings, always a small quantity.

The determination of the temperature, a very difficult and uncertain matter in the case of glass gratings, is here comparatively simple. A sensitive thermometer (Baudin 6156) was kept in contact with the grating, its bulb being carefully shielded by cotton. The construction of the spectrometer made it impracticable effectively to shield the grating from radiation from the observer's body; but the thermometer apparently proved effective in giving the real temperature since no discrepancies in the results could be traced to thermal causes. The thermometer readings were made to 0°·05, and the temperature of observation rarely varied more than two or three degrees from 20° C.

The temperature being thus obtained, the necessary correction was introduced directly into the angle of deviation. Writing the formula for wave-length in the form

$$\lambda = C\, s \sin \varphi,$$

where C is a factor depending on the method in which the grating is used, and differentiating we obtain

$$\frac{\delta s}{s} = -\cot \varphi \delta \varphi,$$

where if we take 1° for the temperature variation $\frac{\delta s}{s}$ is the coefficient of expansion. Whence

$$\delta \varphi = -\frac{\frac{\delta s}{s}}{\cot \varphi} =$$

correction for 1° variation in temperature. For grating III for instance $\delta\varphi = 2''{\cdot}688$ and by this means all the deviations were

reduced to 20°. Writing again the equation for wave-length in the form for the method here used,

$$c=\sin\varphi\cos\theta.$$

Now to obtain the variation in φ due to a change in the angle between the telescopes,

$$\delta\varphi=\tan\varphi\tan\theta\delta\theta.$$

Taking now $\delta\theta=1''$ and φ as found in these experiments

$$\delta\varphi=0''\cdot089.$$

By this means the necessary correction could be introduced in the angle of deviation, but the angle between the telescopes was so nearly constant as to render this correction needless.

The line selected for measurement with III was a sharp one in the green at 5133·95 of Rowland's map. The angle θ between the telescopes was adjusted so that in the eighth order the double deflection was 72°. Eighteen complete series of observations were then obtained, each giving a value of 10φ from which the errors of the circle were completely eliminated. The results in detail were as follows, corrected to 20° on thermometer used,

Date.		φ.		
1887.	Nov. 2,	36°	0′	27″·19
	" 3,	36	0	25 ·87
	" 4,	36	0	24 ·40
	" 5,	36	0	24 ·95
	" 5,	36	0	26 ·83
	" 9,	36	0	26 ·14
	" 16,	36	0	27 ·40
	" 16,	36	0	27 ·37
	" 17,	36	0	27 ·57
	" 22,	36	0	25 ·16
	" 29,	36	0	25 ·69
	" 29,	36	0	25 ·99
	" 29,	36	0	25 ·91
	" 30,	36	0	26 ·10
	" 30,	36	0	25 ·86
	" 30,	36	0	25 ·81
	Dec. 1,	36	0	25 ·68
	" 1,	36	0	25 ·80

The last decimal place is retained simply for convenience in averaging. The mean value of φ is 36° 0′ 26″·07 which reduced for the error of thermometer at 20° gives finally,

$$\varphi=36°\ 0'\ 25''\cdot17.$$

The probable error of this value is 0″·14. The effect of a small error in φ on the resulting wave-length is given at once by

$$\delta\lambda=\cos\varphi\delta\varphi.$$

In this case the error introduced by an error of 1″ in φ is a little less than 1 part in 250000.

The mean value of θ during these measurements was

$$\theta = 6^\circ\ 59'\ 58''{\cdot}6.$$

In case of grating IV the line selected for observation was one of Rowland's standards at w.l. 5914·319 of his preliminary list. It is a very close double, the components being distant from each other something like $\frac{1}{15,000}$ of their wave-length. The double deflection was as before 72° but in the fifth order. As with grating III eighteen series of observations were obtained, with the following resulting values of φ

Date.			ϕ.		
1887.	Dec.	16,	36°	0′	+1″·16
	"	16,	36	0	+0 ·66
	"	16,	36	0	+0 ·67
	"	19,	36	0	+0 ·64
	"	19,	36	0	+1 ·56
	"	19,	36	0	+0 ·85
1888.	Jan.	12,	36	0	−1 ·19
	"	12,	36	0	−1 ·61
	"	12,	36	0	−1 ·79
	"	14,	36	0	−1 ·09
	"	14,	36	0	−0 ·95
	"	14,	36	0	−0 ·89
	"	19,	36	0	−0 ·48
	"	19,	36	0	−0 ·59
	"	19,	36	0	−0 ·49
	"	20,	36	0	+0 ·51
	"	20,	36	0	−0 ·11
	"	20,	36	0	+0 ·55

The mean value, corrected as before for error of thermometer, is:

$$\varphi = 35^\circ\ 59'\ 59''{\cdot}06 + 0''{\cdot}15$$

The effect of this probable error is obviously the same as in case of grating III. The mean value of the semiangle between the telescopes was

$$\theta = 6^\circ\ 58'\ 31''.$$

During the observations with grating III the barometric height reduced to the place of observation was very nearly 762^{mm}, but during the work with grating IV it was phenomenally high, reaching an average value of 766^{mm}, an amount so far from normal pressure as to render a small correction necessary.

The mean temperature during the observations with III was about 21° C., but in case of IV it averaged almost exactly 20° C. varying at most only two or three degrees from that figure.

Measurement of the Gratings.

The comparator on which this, the most important portion of the research, was accomplished was the same one described in my previous paper. It had however been improved in several particulars. The platform carrying the standards had been fitted with smooth rack and screw adjustments, and the microscopes and micrometers were new. The illumination of a grating under the power used,—two hundred and fifty diameters—is by no means an easy matter, and at the same time a powerful and symmetrical illumination is absolutely necessary for the most accurate work, particularly in case of rather small grating spaces. I had been thoroughly dissatisfied with the illumination previously used—a lamp at a suitable distance—and now made a radical change. A three candle-power electric lamp was attached directly to the microscope just below the eyepiece and about a foot above the objects measured. A small mirror carried by an arm screwed to the objective reflected the beam into the Tolles illuminator. A glass bulb filled with water surrounded the light and served the double purpose of stopping radiation and partially condensing the beam upon the mirror above mentioned.

I am aware that such an arrangement is somewhat revolutionary, and it was only after a careful trial that I convinced myself that the heat from so near a source was not injurious.

In the first place it should be noted that the lamp is only used for a few moments at a time and at intervals long compared with the time of observation. Thus the very minute heat wave that reaches the bar through the bulb of water cannot possibly produce a perceptible rise of temperature during the time of an observation, while during the intervals it is completely dissipated.

As an experimental fact, no heating effect whatever is sensible even after a whole day's observations. To show at once this fact, and the general character of an average series of comparisons I subjoin ten comparisons of $Dm_1S^a_2$ with a certain decimeter on glass, made at intervals of about three-quarters of an hour on two successive days. The figures are taken directly from my note book.

Date.		T=
June 1, 1887	$Dm_1S^a_2 = G + 21^{\delta}\cdot3$	17°·4
"	" " + 21·6	17 ·4
"	" " + 22·1	17 ·5
"	" " + 22·1	17 ·5
"	" " + 20·8	17 ·5
"	" " + 20·1	17 ·5
June 2,	" " + 21·4	17 ·0
"	" " + 21·0	17 ·0
"	" " + 21·0	17 ·0
"	" " + 21·0	17 ·1

The temperature was given by a thermometer in contact with S^a_2 and 1δ of the micrometer equalled $0^{\mu}\cdot28$. In a comparison of two standards with such unequal coefficients of expansion as glass and speculum metal, the evil effects of radiation should be at their maximum, but the preceding series, including as it does all the experimental errors and showing an extreme variation of but $0^{\mu}\cdot5$, leaves, I think, little to be desired.

The comparator was placed in a vault some six feet below the level of the street, which was provided with thick double walls with an air space between. This observing room enabled the temperature to be kept down to a daily variation of less than half a degree, the extreme range for several days being frequently less than that amount. Before this vault in the new Physical Laboratory was completed the comparator had been placed in an upper room of one of the old buildings, where it was well nigh impossible to keep anything like a constant temperature, particularly since the heat was unavoidably partially shut off during the night. Owing to this state of affairs the measurement of the gratings on which my preliminary wave-length was based, was made under difficulties and in most of the series necessarily under a rising temperature. Now when a glass standard is measured against a metal one, glass being a notoriously bad conductor, and having a very small coefficient of expansion, if any rise of temperature takes place the length found for the glass will be too small, for responding less readily to a change it will be actually measured at a lower temperature.

It therefore became necessary to re-measure the glass gratings Nos. I and II, to eliminate this source of error, which was done before the results for III and IV were obtained. These gratings are very nearly 3^{cm} long and they were therefore compared with successive triple centimeters of S^a_2 until the fifteen centimeter mark was reached. Grating I was first taken in hand and six complete series of observations were obtained, each micrometer reading being the mean of several, and the extreme limits of temperature variation during the two days occupied by the comparisons being $0°\cdot3$ C. The following gives a summary of the results.

$$\left.\begin{aligned} 5G &= 15^{cm}S^a_2 + 19^{\delta}\cdot0 \\ 5G &= 15^{cm}S^a_2 + 21\cdot5 \\ 5G &= 15^{cm}S^a_2 + 18\cdot1 \\ 5G &= 15^{cm}S^a_2 + 23\cdot9 \\ 5G &= 15^{cm}S^a_2 + 22\cdot6 \\ 5G &= 15^{cm}S^a_2 + 18\cdot3 \end{aligned}\right\} \text{At } 19°\cdot9 \text{ C.}$$

Hence combining these and reducing them to the standard temperature of 20° we have:

$$60000 \text{ spaces} = 5G = 15^{cm}S^{a}_{2} + 5^{\mu}\cdot 2 \text{ at } 20°$$

The micrometer constant here used was that of the new micrometer where $1\delta = 0^{\mu}\cdot 257$.

In precisely the same way Grating II was remeasured, the six series giving the following relations

$$\left.\begin{array}{l} 5G = 15^{cm}S^{a}_{2} + 157^{\delta}\cdot 4 \\ 5G = 15^{cm}S^{a}_{2} + 154\cdot 9 \\ 5G = 15^{cm}S^{a}_{2} + 154\cdot 5 \\ 5G = 15^{cm}S^{a}_{2} + 152\cdot 4 \\ 5G = 15^{cm}S^{a}_{2} + 154\cdot 9 \\ 5G = 15^{cm}S^{a}_{2} + 162\cdot 4 \end{array}\right\} \text{At } 19°\cdot 8 \text{ C.}$$

Combining and reducing these results as before we have the equation

$$42640 \text{ spaces} = 5G = 15^{cm}S^{a}_{2} + 39^{\mu}\cdot 9 \text{ at } 20°$$

The temperature variation in the two days of observation was only 0°·2.

Gratings III and IV were then measured. In this case a large number of comparisons were obtained at both high and low temperatures with the object of detecting any differences which might exist between the coefficients of expansion of the gratings and those of the speculum metal standards. III and IV being a little over a decimeter in length were very easy to measure, particularly since the lines were very sharp and of approximately the same width as those on the standards.

III proved to have sensibly the same coefficient as the standards. I subjoin the comparisons made at or very near 20°.

$$\begin{array}{ll} G = Dm_{1}S^{a}_{2} & + 32^{\delta}\cdot 9 \\ G = \text{“} & + 33\cdot 0 \\ G = \text{“} & + 32\cdot 7 \\ G = \text{“} & + 33\cdot 2 \\ G = \text{“} & + 32\cdot 3 \\ G = \text{“} & + 32\cdot 6 \\ G = \text{“} & + 34\cdot 5 \\ G = \text{“} & + 33\cdot 4 \\ G = \text{“} & + 34\cdot 2 \\ G = \text{“} & + 32\cdot 6 \end{array}$$

Combining these and other series of observations gives finally

$$28418 \text{ spaces} = G = Dm_{1}S^{a}_{2} + 8^{\mu}\cdot 5 \text{ at } 20°$$

It should be noted that the extreme variation in the above series is $2^{\delta}\cdot2$, very nearly $0^{\mu}\cdot5$, or one part in two hundred thousand.

In the case of IV the coefficient appeared to be somewhat smaller than that of S^a_2. The range of temperature secured was not large but as nearly as could be ascertained the coefficient is about $16^{\mu}\cdot1$ per meter per degree, while that of the standards is $17^{\mu}\cdot9$ per meter per degree. However, since the measurements of φ made with IV were distributed with a tolerable degree of symmetry on both sides of 20°, any error due to an inexact value of the coefficient of expansion would appear mainly in the probable error in φ The variation found would, as a matter of fact have changed the final value of φ by less than $0''\cdot2$.

The comparisons of IV made near 20° were as follows:

$$\begin{aligned}
G &= Dm_1S^a_2 + 35^{\delta}\cdot8\\
G &= \text{“} + 35\cdot5\\
G &= \text{“} + 35\cdot6\\
G &= \text{“} + 36\cdot0\\
G &= \text{“} + 34\cdot0\\
G &= \text{“} + 35\cdot8\\
G &= \text{“} + 34\cdot6\\
G &= \text{“} + 36\cdot3\\
G &= \text{“} + 33\cdot3\\
G &= \text{“} + 36\cdot7
\end{aligned}$$

Combining these and the other observations,

$$39465 \text{ spaces} = G = Dm_1S^a_2 + 9^{\mu}\cdot1 \text{ at } 20°.$$

The probable error of the relations found for III and IV can hardly exceed one part in a million so far as the distance between the terminal lines selected is concerned. These terminal lines were varied at each comparison so that while each of the above relations represents 39,465 spaces, the lines measured between, though in the same vicinity, are seldom or never identical.

In gratings I, II, III the number of spaces was very easily counted as the dividing engine automatically rules every hundredth line longer, and every fiftieth line shorter, than the others. In grating IV the number of spaces was found readily enough by ruling at a known temperature the terminal lines of a test plate almost exactly a decimeter long, and containing a known number of lines. A comparison of this with the grating gave the quantity required.

Calibration of the Gratings.

In my previous paper the need and method of determining the errors of ruling in a grating were briefly noticed. It is fitting here to enter somewhat more into detail.

The grating space is never perfectly uniform throughout the whole extent of the ruled surface. The variations may be in general classed as regular and irregular. In the first class we put variations in the grating space which are purely periodic or purely linear. These produce respectively "ghosts," and difference in focus of the spectra on opposite sides of the normal. Either fault might be large enough to unfit the grating for wave length determination, and would be always undesirable, but nevertheless would introduce no gross errors into the result. Variations of the second class include the displacement, omission or exaggeration of a line or lines, and what is of great importance, a more or less sudden change in the grating space producing a section of the grating having a grating space peculiar to itself. The former types of accidental error, unless extensive are harmless, and are present in most gratings usually showing as faint streaks in the ruling. It is with the last mentioned error that we mainly have to do.

Consider a grating the space of which is sensibly uniform except throughout a certain portion. Let that portion have a grating space distinctly larger or smaller than that of the remainder of the grating. If the abnormal portion is a considerable fractional part of the whole grating it will, in general, produce false lines and injure or ruin the definition of the grating. Such a grating we should nowadays throw aside as useless, although many of the older gratings are thus affected. Suppose however that the abnormal portion is confined to a few hundred lines. Such a series of lines will have little brilliancy and less defining power and consequently will simply diffuse a certain amount of light without either producing false lines or, in general, injuring the definition. In short, when the full aperture of the grating is used, the spectra produced will be due only to the normal grating space, the abnormal portion having little or no visible effect. If however we attempt to evaluate the grating space by measuring the total length of the ruled surface and dividing it by the number of spaces therein contained, we shall obtain an incorrect result, since this average grating space, including, as it does, the abnormal portion, will be necessarily different from the normal grating space which produces the spectra observed.

In general if n be the total number of spaces and s the normal grating, space the length of the ruled surface will be $ns+A$, where A is a quantity depending on the magnitude

and nature of the abnormal portion. It will have for its maximum value $\Sigma(s-s')$, where s' is the varying grating space, in the case when the change in the space is so local and sudden as to produce no effect at all on the spectrum; and will be variously modified by the considerations now to be mentioned. If we could always assume that the abnormal portion of the grating produced no effect on the spectrum the elimination of errors of ruling would thus become comparatively simple. But in practice it is not very uncommon to find gratings in which there are several portions where the spacing is abnormal, in one case perhaps producing no effect, in a second producing false lines and in a third causing a faint shading off of the lines. For an abnormal portion will produce no effect, a slight shading or reduplicated lines, according to its extent and the amount of its variation from the normal.

The following experiment will readily show the laws which govern these errors of ruling. Place a rather bad grating—unfortunately only too easily obtained—on the spectrometer, and setting the cross-hairs carefully on a prominent line, gradually cover the grating with a bit of paper, slowly moving it along from one end. In very few cases will the line stay upon the cross-hairs. A typical succession of changes in the spectrum is as follows: Perhaps no change is observed until two-thirds of the grating has been covered. Then a faint shading appears on one side of the line, grows stronger as more and more of the grating is covered, and finally is terminated by a faint line. Then this line grows stronger till the original line appears double and finally disappears leaving the displaced line due to the abnormal grating space. This description, I regret to say, is from the examination of a grating which had been used for the determination of absolute wave-length.* This case is exceptionally complete, but even with a very good grating minute displacements can usually be noticed.

When the abnormal portion is sufficiently extensive to produce a faint shading along one side of the lines when the full aperture of the grating is used, the effect of the error on the resulting wave-length may be in part eliminated by the fact that the shading would displace the apparent center of the line and hence slightly change the observed angle of deviation. For this reason a grating so affected would be likely to give results varying with the order of spectrum used, since the appearance of the line would vary somewhat with the illumination. It is at once apparent, however, that no combination of the results from different orders of spectra can possibly eliminate the class of errors we are discussing, since the alge-

* Not by the author it is almost needless to add.

braic sign of the error will be the same for all orders and it will be in every case a nearly constant fraction of the wave length.

The problem before the experimenter is then the following: To detect the existence and position of any abnormal portion of the grating in use, to separate as far as possible such portions as produce a visible effect from those which do not, and thus finally to determine the proper value to be assigned to the quantity A.

The investigation is somewhat simplified by the fact that, for the most part, abnormal spacing occurs at an end of the ruled surface, generally at the end where the ruling was begun, since, when the engine is started it is likely to run for some little time before it settles down to a uniform state. Then, too, one is able to disregard the slight and gradual variations in the grating space which appear in every grating, since their effects will in general be integrated in the spectrum produced.

It only remains therefore to study those larger and more sudden changes which can produce a sensible error in the result. It is evident that the process of examination indicated above will serve to detect the more extensive faults, together with any errors of figure in the surface, but an abnormal portion consisting of only a few hundred lines will not have resolving power enough to produce a marked effect. Making then a slit in a card just wide enough to expose a sufficient number of lines to give tolerable definition, one can examine the grating section by section, and still further discriminate between the normal and abnormal spacing, errors of figure being included as before. But as the number of abnormal spaces decreases a point will be reached when this method breaks down completely, and since the error in the resulting wave-length may be as large in this case as when the fault is more extended, another method must be sought. So far as I know the only method which will detect and evaluate all these errors is that which I have called calibration, measuring the relative lengths of n grating spaces taken successively along the ruled surface. The process employed was as follows. The stops of the comparator were set as close together as practicable, limiting the run of the carriage to a distance which varied in different cases from 4 to 10^{mm}. Then the grating to be examined was brought under the microscope and micrometer readings were taken on the lines just within the run of the carriage; the grating was then moved along about the length of the run and the process repeated till the whole grating had been gone over. The variations in the micrometer readings then gave the variations in the length of n spaces in different parts of the grating. The only assumption involved was that the variation in the different sections did not

amount to an entire space, an hypothesis quite secure in gratings with spaces as large as those employed. It was thus possible to determine quite accurately the variations in the grating space throughout the whole grating.

It should be noted that since these variations may be of almost any kind and magnitude the errors produced by them will not in general be eliminated by combining the results obtained from several gratings. It may happen that the gratings used by one experimenter will have errors that will counterbalance each other, while those used by another will all have errors of the same sign. For instance, by the merest accident the gratings used by the writer gave nearly identical results corrected and uncorrected, while those used by Peirce uniformly required a reduction in the resulting wave-length. The number of gratings used by a given investigator is however so small that the errors will very seldom be eliminated, while no combination of the results obtained from different orders of the same grating can produce any useful effect whatever.

Each of the gratings used in this research was examined minutely by the above methods and in each was found an abnormal portion of one sort or another. Of eight gratings which I have calibrated all have shown a similar error and of more than twenty which I have examined in the spectrometer only one (grating III) failed to show an abnormal section at one end. Since this is the commonest form of the error in question, it is but natural to inquire why it cannot be avoided by covering the defective end. The reason is simple enough. By stopping out the defective portion the grating is reduced to an incommensurable length which enormously increases the difficulty of measuring it. A grating which is in length some convenient submultiple of a meter is easy to measure with a comparatively high degree of exactness, but one which is, say, twenty seven millimeters long, is exceedingly difficult to measure accurately since it involves a long micrometer run or the errors of subdivision down to single millimeters. It is therefore better to use the full aperture of the grating and find A by calibration.

In calibrating the gratings used, I divided I and II, which were thirty millimeters long, into six sections of 5^{mm}, and the large gratings III and IV into centimeters. Each grating was carefully gone over five times and the mean result taken. The following corrections were found.

The actual variations found in each grating are given below, the figures given being the difference of n lines from the distance between the stops, the lines being taken in the consecutive sections of the gratings.

Grating I.

Sections	1	2	3	4	5	6
Residuals,	$0^{\mu}\cdot78$	0·98	0·81	1·03	0·86	1·24

Grating II.

Sections	1	2	3	4	5	6
Residuals,	$2^{\mu}\cdot07$	1·93	1·52	1·68	1·31	0·45

Grating III.

Sections	1	2	3	4	5	6	7	8	9	10
Residuals,	$2^{\mu}\cdot80$	2·85	1·77	2·77	2·70	2·77	2·67	2·64	2·73	2·77

Grating IV.

Sections	1	2	3	4	5	6	7	8	9	10
Residuals,	$0^{\mu}\cdot31$	0·28	0·35	0·43	0·40	0·43	0·31	0·35	0·28	0·82

The calibration of III is worth describing in detail. Centimeter 3 was evidently too long. I therefore measured the centimeters from 15 to 25^{mm} and from 25 to 35^{mm}. The former was quite normal but the latter showed an increase almost identical with that of the whole third centimeter. I then examined the grating in a strong light and detected at 27^{mm} from the end, a faint line, such as usually indicates a few wavering lines caused perhaps by dust under the diamond point. Placing, however, this line under the microscope a band of perhaps twenty lines appeared with spacing noticeably wider than usual. Here was a very serious flaw in a grating to all appearance absolutely perfect. A most critical examination in the spectrometer of course failed to detect it, but it was both detected and located with unerring certainty by the process of calibration. Micrometrical measurements on this group showed an excess of about $2^{\mu}\cdot5$ over an equal number of spaces elsewhere on the grating. This quantity of course had to be taken account of in connection with the previous calibration.

The deduction of the necessary corrections from the data given by calibration requires no little care and judgment, and can be properly done only in connection with a detailed study of the spectra given by various portions of the gratings concerned. For the four gratings used by the author, these corrections, applied directly to the lengths of the gratings in the form of the quantity A before mentioned, are very nearly as follows:

Grating.	A
I	$-0^{\mu}\cdot10$
II	$+\ 0\cdot40$
III	$-\ 2\cdot00$
IV	$+\ 0\cdot45$

It should be distinctly understood that the corrections deduced from the calibration are necessarily only approximate. A very minute examination of a grating on the spectrometer is impossible, since a small section of the ruled surface has not sufficient resolving power to give measurable spectra. On the other hand, while calibration gives the variations of the grating space with a high degree of exactness, it obviously cannot definitely decide how far these variations are integrated in the spectrum measured. Consequently while calibration will in every case give a valuable approximation, it must necessarily leave residual errors.

In these experiments the gratings were always measured parallel to the terminations of the lines. Consequently the length of each grating as found directly must be multiplied by cos $(90^\circ - \alpha)$, where α is the angle made by an individual line with the line formed by the locus of the terminations. In case of gratings I, II, III this angle was found by measuring a test plate as described in my previous paper and was found to be within a very few seconds of 89° 56′.

Grating IV ruled on the new engine was tested by measuring the sides and diagonals of the ruled surface and gave an almost exactly identical value of α. No correction therefore need be introduced for this cause, since cos $(90^\circ - \alpha)$ does not differ sensibly from unity.

Final result for Absolute Wave-length.

Only one equation needs to be added to those already given for S^a_2. This is the one for the third 5^{cm} space, necessary to determine the absolute length of the first 15^{cm}. 5^{cm}, (3) and (4) were compared and the following relation was found between them: (4) = (3) + $0^{\mu}\cdot4$. The relation found in 1885 was (4)=(3)+$1^{\mu}\cdot1$. Consequently (3) has not sensibly shortened and nearly the whole change found in S^a_2 has taken place in the last five centimeters. Writing now the absolute lengths of

$$Dm_1\ S^a_2 \text{ and } 15cm.\ S^a_2,$$

$$Dm_1\ S^a_2 = 100\cdot00666^{mm} \text{ at } 20^\circ.$$
$$15cm\ S^a_2 = 150\cdot00897 \text{ at } 20^\circ.$$

Applying now the relations found for grating I in the foregoing section,

$$s = 0\cdot002500226^{mm}$$

And since

$$\varphi = 45^\circ\ 1'\ 48''\cdot24$$
$$\lambda = 5896\cdot18$$

Similarly for grating II,

$$s = 0\cdot003519041^{mm}$$
$$\varphi = 42^\circ\ 4'\ 59''\cdot28$$
$$\lambda = 5896\cdot23$$

Computing the similar quantities for the speculum metal gratings III and IV, for grating III,

$$s = 0{\cdot}0035193^{58\,mm}$$
$$\varphi = 36^\circ\ 0'\ 25''{\cdot}17$$
$$\theta = 6^\circ\ 59'\ 58''{\cdot}56$$
$$\lambda = 5133{\cdot}89$$

and for grating IV,

$$s = 0{\cdot}0025343^{06\,mm}$$
$$\varphi = 35^\circ\ 59'\ 59''{\cdot}06$$
$$\theta = 6^\circ\ 58'\ 31''$$
$$\lambda = 5914{\cdot}37$$

Reducing now these latter wave lengths to the corresponding values of D_1, introducing the barometric corrections and combining, the final results for that line are

Grating	W. L.
I	5896·18
II	5896·23
III	5896·15
IV	5896·17

Finally, then, the mean value of the absolute wave-length of D_1 in terms of the mean value assigned to $S^a{}_2$ is

5896·18

in air at 760^{mm} pressure and 20° C. temperature, or *in vacuo*,

5897·90

It is no easy matter to form an estimate of the probable error of this final result. So far as errors of observation go, the result should be correct to within one part in half a million, but there are so many complex sources of constant errors in this problem that such a statement means little. My present result exceeds the estimated probable error of my former result considerably, though it falls within the limit set by Prof. Rowland and myself for the possible error and noted in his paper on "Relative Wave-length" of the same date as my own. The cause of this discrepancy is partly due to the varying temperature under which the glass gratings were first measured, and partly to the change in the value assigned to the standard of length.*

Then too, the corrections applied to gratings II and III may be slightly in error. Taking into account all these sources of uncertainty it is my opinion that the above final result is not likely to be in error by an amount as great as one part in two hundred thousand.

* In terms of the length I originally assigned to $S^a{}_2$ the wave-length of D_1 would be 5896·14, while if the value deduced from the Berlin comparison were taken it would be 5896·22. The wave-length quite certainly lies between these values, but the proper weight to be given to the Berlin comparison relatively to the others is rather uncertain.

Taking the above value of the absolute wave-length and applying the appropriate corrections to some of the fundamental lines given in Prof. Rowland's paper (this Journal, March, 1883) the wave-lengths of the principal Fraunhofer lines in air at 20° and 760^{mm} are,

A	(line between "head" and "tail" of group)	7621·31
B	"	6884·11
C		6563·07
D_1		5896·18
D_2		5890·22
E_1		5270·52
E_2		5269·84
b_1		5183·82
F		4861·51

Comparisons between these wave-lengths and the older ones become somewhat uncertain toward the ends of the spectrum since the appearance of lines like A, B, G and H vary so much with the dispersion employed. The relative wave-lengths above given are certainly exact to within one part in half a million.

It may not be out of place here to discuss the most recent work on this problem. Just before the publication of my first paper the very elaborate paper of Müller and Kempf appeared. Their work is a monument of laborious research and it is unfortunate that so much time should have been spent in experiments conducted with glass gratings of small size and inferior quality. Since the invention of the concave grating, it is a waste of energy to make micrometric measurements with plane ones, and this statement could hardly be corroborated more strongly than by the relative wave-lengths given by Müller and Kempf. The probable error of their wave-lengths is in general not less than one part in two hundred thousand. That the value assigned by them to the absolute wave-length is as near the truth as it probably is, is due to no lack of faults in the gratings. Their results for the line D_1 were as follows:

Grating.	W. L.
"2151"	5896·46
"5001"	5896·14
"8001"	5895·97
"8001L"	5896·33

A discussion of these errors as exemplified in the paper under consideration would take up too much space to be inserted here, but one or two points are worthy of notice. When a grating gives different results in the different orders, it is evident that there are in it serious errors of ruling, and the maximum amount of the variation will give a rough esti-

mate of their size as compared with those of other gratings. Applying this test, the four gratings rank as follows: "5001," "8001 L," "2151," "8001," where the first which gave for the w. l. 5896·14, had no sensible variation in the different orders and the last, which gave 5895·97, varied in the most erratic fashion. It by no means follows, however, that because a grating gives identical results in the various orders, it is therefore free from errors of ruling. Witness Grating III of this paper in which the error was of a kind which could not be detected at all in the spectrometer. Yet it was large enough to give, if neglected, 5896·28 for the wave-length of D_1.* Speaking of errors in gratings a case in point is the work of Peirce. On account of the reasons heretofore noted Peirce's standards of length are somewhat uncertain in value so that no definite correction can be as yet applied to his wave-length from this cause. Three of his gratings, however, I have calibrated, and each of them showed an error tending to diminish the wave-length. If the mean result obtained from these had been assumed to be correct it would have been equivalent to the introduction of a constant error. Peirce's preliminary result is for this reason too large by more than one part in a hundred thousand; how much more, it is impossible to say without knowing the results obtained from each grating and so being able to apply the corrections found. Peirce's method was such as should have secured very excellent results and such will undoubtedly follow a further investigation of the standards and gratings. Still another recent determination is that by Kurlbaum, who used two good sized speculum metal gratings and measured them with particular care. Like the previous experimenters he neglected, although he did not ignore, the errors of ruling and consequently the results he obtained are somewhat in doubt. A serious objection, moreover, to his work is the very small spectrometer he used. To undertake a determination of absolute wave-length with a spectrometer reading by verniers to 10″ only, and furnished with telescopes of only one inch aperture is simply courting constant errors. More especially is this true since it would be hard to devise a method more effective in introducing the errors of ruling, than to use a grating with telescopes too small to utilize its full aperture, and then determine the grating space by measuring the total length of the ruled surface. Kurlbaum's gratings, too, were of an unfortunate size, 42 and 43^{mm} broad respectively, and consequently by no means easy to measure. On the whole his result, 5895·90 is not surprising.

*The results given by the gratings used by the author, neglecting the correction A would be as follows:

I. 5896·20; II, 5896·14; III, 5896·28; IV, 5896·12

Curiously enough the mean would be practically unchanged.

The agreement of relative wave-lengths as determined by different experimenters unfortunately gives no measure as to the accuracy of the work. The relative wave-lengths as determined by Müller and Kempf and by Kurlbaum agree in general to within 1 part in 100,000; the absolute wave-lengths assigned by these experimenters vary by more than 1 part in 30,000.

A very ingenious flank movement on the problem of absolute wave-length has been made by Macé de Lépinay. His plan was to use interference fringes in getting the dimensions of a block of quartz in terms of the wave-length, and then to avoid the difficulties of the linear measurement by obtaining the volume through a specific gravity determination. His results do not indicate, however, experimental accuracy as great as can be obtained by the usual method, and the final reduction unfortunately involves a quantity even more uncertain than the average standard of length, i. e., the ratio between the meter (?) and the liter.

It may be interesting here to collect the various values which have been given for the absolute wave-length within recent years. Results are for the line D_1.

Mascart	5894·3
Van der Willigen	5898·6
Ångström	5895·13
Ditscheiner	5897·4
Peirce	5896·27
Ångström corrected by Thalen	5895·89
Müller and Kempf	5896·25
Macé de Lépinay	5896·04
Kurlbaum	5895·90
Bell	5896·18

These figures are discordant enough. When beginning the present work, I had hoped that it would prove possible to make a determination of absolute wave-length commensurate in accuracy with the relative wave-lengths as measured by Prof. Rowland. This hope has proved in a measure illusory, by reason of the small residual errors of the gratings and the greater uncertainty involving the standards of length. I feel convinced, however, that the result reached is quite near the limit of accuracy of the method. It should be remembered that any and every method involves the uncertainty of the standards of length, an uncertainty not to be removed until a normal standard is finally adopted and exact copies of it distributed. And as far as experimental difficulties are concerned, the next order of approximation will involve a large number of small but troublesome corrections, such as the effect

of aqueous vapor on atmospheric refraction, varying barometric height, the minute variations in the grating space, failure of thermometer to give temperature of grating exactly, and countless others which will suggest themselves only too readily.

Aside from the use of gratings, decidedly the most hopeful method as yet suggested is that due to Michelson and Morley.* Theoretically the plan is particularly simple and beautiful, consisting merely in counting off a definite number of interference fringes by moving one of the interfering mirrors and measuring, or laying off upon a bar, the resulting distance. The mechanical difficulties in the way, are however formidable, and whether or no they can be surmounted only persistent trial can show. The possible sources of error are of much the same type and magnitude as those involved in the comparison of standards of length, and if these errors are avoided, the uncertainty concerning the standards still remains. Whether or no the practical errors of the method are greater or less than with gratings only experience can prove. Certainly if the method is capable of giving exact results it is in the hands of one able to obtain them from it.

In closing this paper I can only express my sincerest gratitude to the various friends who have done all in their power to facilitate my work, and especially to Professor W. A. Rogers who has been tireless in his endeavors to determine the true value of the standards of length; to Mr. J. S. Ames, Fellow in this University, who has given me invaluable aid in the work with metal gratings; and to Professor Rowland who has furnished all possible facilities and under whose guidance the entire work has been carried out.

Physical Laboratory, Johns Hopkins University, March, 1888.

Art. XXXI.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGee. (With Plates VI and VII.)

(Continued from page 330.)

The Columbia Formation.

General Characters.—The Columbia formation exhibits two phases which, although distinct where typically developed, intergraduate. The thicker and more conspicuous phase occurs commonly along the great rivers at and for some miles below the fall line, and may be designated the *fluvial* phase; while the thinner generally forms the surface over the remainder of the Coastal plain, and may be designated the *interfluvial* phase.

* This Journal, III, xxxiv, 427.

The first phase is bipartite, the upper division consisting of massive or obscurely stratified brick clay, loam, and fine sand, and the lower of stratified and cross laminated gravel and coarse sand, containing abundant erratic bowlders; while the second consists of an indivisible bed of gravel, sand, clay, etc., chiefly of local origin and thus varying from place to place though tolerably homogeneous in each exposure. The first phase, too, is confined to limited altitudes, approximately constant on each river but rising northward, while the second occurs indiscriminately at the highest and lowest altitudes within the Coastal plain, its thickness culminating at the lower levels and along the coast.

The Fluvial Phase.—The bipartite phase of the formation is well developed along all of the larger rivers of the Middle Atlantic slope, but most characteristically and extensively on the Potomac, the Susquehanna, and the Delaware.

The deposits on the Potomac.—Washington lies within a rudely triangular amphitheater opening southward, into which the Potomac falls from the northwest and the Anacostia from the northeast, the former passing from torrential to estuarine condition and turning southward within the limits of the city. The western side of the amphitheater is the Piedmont escarpment, which south of the city is a terraced or irregular slope rising to a somewhat undulating plain 200 to 425 feet in altitude; the eastern side is the line of bluffs overlooking the Anacostia and rising into two broad terrace plains 175 and 275 feet in height respectively; and the northern confine is the deeply ravined margin of a terrace 200 feet in altitude stretching from the breach made by the Potomac in the Piedmont escarpment directly eastward to the broader valley of the Anacostia three or four miles above the confluence. The floor of the amphitheater is a series of low terraces rising from a few feet below to about 100 feet above tide, the most conspicuous two being about 40 and 80 feet in altitude respectively. To the southward the amphitheater opens into a broad valley occupied partly by the Potomac estuary and partly by a low but extended series of terraces, of which the best developed members are about 20 and 40 feet above tide respectively.

Throughout this amphitheater the fluvial phase of the Columbia formation is the prevailing superficial deposit up to 150 feet above tide; except where manifestly eroded or buried beneath modern alluvium, it is everywhere exposed; all of the lower and many of the higher terraces are built of it; and it unquestionably lines the estuaries of both the Potomac and the Anacostia beneath the recent alluvium. The relation between the deposit and the topographic configuration is striking, and

too intimate to be fortuitous. Everywhere west of the Anacostia-Potomac channel (the deposit does not occur east of the rivers) the limiting boundary of the fluvial phase of the formation is the 150 foot contour; and the limit within which it exhibits a certain notable and well defined type is the 90 foot contour.

Within the amphitheater the formation varies considerably in structure and composition and in the relative thickness of the two members—the basal member being best developed centrally and near the entrance to the Potomac gorge, and the superior and finer member reaching the best development and greatest volume peripherally and at points distant from the gorge. The section in the central part of the city of Washington is, however, typical; and two exposures so located, which together form a general section of the fluvial phase of the formation, are shown in the accompanying plates.

Plate VI is reproduced mechanically (by the Moss process) from a photograph of the exposure on the north side of E street between 1 and 2 southeast. The upper member is homogeneous loam, rather too sandy for use as a brick clay, either massive or obscurely stratified, containing a few small pebbles irregularly disseminated or arranged in layers. On mechanical analysis the loam is found to consist of (1) fine silty or clayey particles of impalpable fineness, intimately mingled with (2) sand grains of variable size, form and composition, and with (3) gravel of all sizes from that of coarse sand to that of the pebbles shown in the plate; the relative proportions being perhaps 50 per cent of impalpable clay and silt, 35 or 40 per cent of sand grains up to $\frac{1}{8}$ inch in diameter, and the balance gravel grains and larger pebbles. The homogeneous loam graduates downward imperceptibly into obscurely stratified sandy and gravelly loam in which sand from $\frac{1}{8}$ inch downward constitute some 40 per cent, gravel from $\frac{1}{8}$ inch upward about 30 per cent, pebbles from an inch upward perhaps 20 per cent, and impalpable silt not more than 10 per cent of the volume—the structure remaining unchanged save that the stratification becomes more and more distinct toward the base. The gravelly loam graduates in turn into a bed of stratified sand and fine gravel, sometimes cross-laminated, with occasional pebbles up to 3 or 4 inches disseminated through it. This bed is practically destitute of impalpable silt, and is screened for building sand. The stratified sand passes rather abruptly, but with some interstratification, into a heterogeneous mass of coarse sand, gravel, pebbles and bowlders up to a foot in diameter.

Plate VII, also reproduced mechanically from a photograph, supplements Plate VI. The exposure occurs on the opposite side of the street and, extending nearly to the base of the Co-

lumbia formation, exhibits the typical aspect of the lower member—the greater part of the superior loam having been artificially removed long before the recent excavation was made. The uppermost stratum consists of pebbly and sandy loam corresponding to but somewhat coarser than the basal portion of the upper member in Plate VI; and in this section, too, the stratum graduates insensibly into stratified sand, which in turn passes imperceptibly into the gravel bed at the summit of the lower member.

The gravel deposit constituting the lower member is distinctly but irregularly stratified and rather indefinitely tripartite. The uppermost stratum is a bed of gravel and sand similar to but thinner than that above the stratified sand, containing rounded and sub-angular bowlders up to over a foot in diameter (commonly arranged in beds), lenticular layers and pockets of sand, etc.; the next stratum is a regularly bedded mass of clay and loam, evidently derived largely from the Potomac formation, which is locally inclined; and finally at the base there is another bed of gravel (imperfectly shown in the plate) resting on an irregular surface of purple-brown Potomac clays. Combining the three strata and analyzing their constituents, it is found that perhaps 20 per cent consist of pebbles and bowlders from an inch to a foot or more in diameter, some 25 per cent of gravel and pebbles from $\frac{1}{8}$ inch to one inch in diameter, about 30 per cent of finer sand, and the remainder (including the redeposited Potomac clay) of impalpable silt or clay; and examination of the pebbles and bowlders shows that nearly all of the larger are angular or sub-angular and either of Piedmont gneiss or of quartz undistinguishable from the vein quartz of the Piedmont zone, while 75 or 80 per cent of the smaller are well rounded and of quartz and quartzite similar to those of the lower member of the Potomac formation.

These sections occur about three miles southeast of the gap cut by the Potomac river in the Piedmont escarpment, and in the line of the old outer gorge. Nearer the gap the superior member attenuates, and the gravel bed thickens and becomes coarser until in some sections fully one-half of the formation is made up of pebbles and bowlders up to four or five feet in diameter; to the eastward the loam increases in thickness and homogeneity, its pebbles disappear, and the stratification becomes more regular, while the basal member attenuates and the pebbles and bowlders of which it is composed diminish gradually both in size and abundance; to the southward and further from the gap the upper portion of the loam is a homogeneous brick clay, its lower portion is a stratified sand, and the lower member of the formation is represented only by a thin bed of

gravel and small bowlders; and still further southward, as at Alexandria, the superior loam becomes fine and silty, and there is but an inconspicuous bed of pebbles, with no large bowlders, at the base.

Most of the materials composing the formation in the Washington amphitheater may be readily traced to their sources: nine tenths of the larger angular and sub-angular bowlders are either (1) gneiss identical with that exposed in the gorge of the Potomac river within a few miles to the westward, or (2) quartz undistinguishable from that of the veins intersecting the gneiss; the well rounded quartz and quartzite pebbles are indistinguishable from those of the Potomac formation, and indeed in some cases Potomac outliers unquestionably *in situ* graduate insensibly into taluses which descend the slopes and in turn graduate into the Columbia gravels; the intercalated layers of plastic clay and accumulations of arkose are lithologically identical with certain characteristic phases of the Potomac formation; the sand, clay and loam sometimes resemble the residuary products formed by the disintegration of the adjacent Piedmont gneisses *in situ* so closely as to be distinguished only by structural features; and in all cases the petrographic identity is unquestionably indicative of the source of the material.

The Genesis of the Deposits.—An essential element in any philosophic classification of the rocks of the earth is genesis, and geologic science has now reached a stage in which processes and products, agencies and results, are commonly correlated, and in which at least the broader classifications are genetic.

There are recognized five principal categories of agencies by which the various superficial deposits of the earth are produced, viz: chemic, igneous, glacial, aerial and aqueous.

Now on comparing the upper member of the fluvial phase of the Columbia formation with the known products of each of these categories of agencies, it becomes evident that the deposits were not produced by either of the first two classes of agencies, since they have no distinctive features in common with chemic and igneous deposits; that they are not glacial, since they are too regularly and continuously stratified, since the two members are distinct in structure and composition and yet intergraduate, and since the pebbles and bowlders are neither striated nor polished; that they are not aerial since the materials are coarser and more continuously bedded than those transported by winds; and hence that the deposits are aqueous in origin. By legitimately extending the same process of reasoning it might equally be shown that they are not fluviatile, torrential, lacustral, nor marine, and indeed that they can only be a sub-estuarine delta of the river on which they occur.

The same conclusion is reached by the converse process of reasoning. At Washington the Potomac river passes from fluviatic to estuarine condition, and the materials transported by the river proper are precipitated in the estuary. The opportunities for examination of these sediments are limited, because they are seldom exposed above tide level (subaerial alluvium being significantly absent along the fall line margin of the Coastal plain); but the numerous borings made in engineering operations indicate that the sub estuarine deposits opposite Washington consist predominantly of fine silt or clay, and subordinately of sand and gravel, with occasional pebbles and bowlders of considerable dimensions either scattered or in beds. In brief, the deposits of the Potomac estuary of the present at Washington differ from the upper division of the fluvial phase of the Columbia formation only in the larger proportion of silt and the smaller size of interspersed bowlders; and below Washington the modern estuarine deposits become progressively finer to and beyond Alexandria, just as do the deposits of the Columbia formation. Now the precise conditions of genesis of the modern sub-estuarine deposits are known: the silt is carried down the river and into the estuary at all stages but most abundantly during freshets to either settle immediately in the slack water or sweep back and forth with the tide until flocculation and more gradual deposition finally take place; the fine sand is similarly transported into the estuary and dropped toward its head; most of the coarse sand, gravel and pebbles are swept over the falls or collected in the gorge of the Potomac by the raging torrent which the river becomes during its freshet stages, and are quickly deposited in the upper part of the estuary; while the larger pebbles and bowlders, together with some of the smaller, are gathered along the river and floated into the estuary by the ice floes with which the torrent is laden during spring freshets; and the distribution of the various materials, fine and coarse, is affected by the strength of the currents, by local eddies and basins, and by distance below the mouth of the gorge, while the area of deposition is determined by present tide level. Were the land in the vicinity of Washington to be elevated 150 feet, and were this level to be maintained until the sub-estuarine deposits now in process of formation were dissected by erosion, desiccated by draining, and decolored by oxidization, they would unquestionably form a homologue of the upper member of the Columbia formation, differing from it only in coarseness of materials and in geographic extent; and the modern deposit, like the older, would rise upon the valley sides to the shore line contour, and its surface would similarly form a broad terrace plain.

The altitude of the old delta now exposed as the Columbia formation indicates submergence of about 150 feet during the period of its deposition; and such submergence is attested not only by the deposits but by an extensive system of terraces. The Columbia formation itself forms, within the Washington amphitheater, two distinct terrace plains, modified by erosion and culture yet each miles in extent, together with several others of less area; the upper level of the deposit is marked by broad shore lines on both sides of the head of the estuary and by a rock shelf in the gorge of the Potomac half a mile in average width and fifteen miles long; southwest of Washington there is a wave-fashioned plain, 220 feet above tide, which is more than twenty-five square miles in area and so little modified by erosion that considerable tracts are imperfectly drained; a more deeply ravined plain of like altitude five square miles in area forms the marginal portion of the Piedmont plateau to the northward of Washington; beyond the Anacostia there are equally distinct terrace plains, that of 175 feet above tide at St. Elizabeth's Insane Asylum being so imperfectly invaded by erosion and so level to the very verge of the river bluffs that drainage is imperfect over fully a square mile of its area; and in many other localities, and at all altitudes up to 250 feet or more, broad terraces abound. The extensive terracing of the tract gives origin to a striking topography of plains and scarps, through which profiles, drawn in any direction, exhibit characteristic combinations of horizontal lines and steep slopes. Independently of the deposits, the terraces and shore lines in the Washington amphitheater prove submergence of the land to a depth of over 250 feet—the deposits at the highest levels representing rather the interfluvial than the fluvial phase of the Columbia formation.

While nothing more than comparatively brief submergence of 150 or more feet was required to produce the upper member of the Columbia formation, other conditions were required to produce the coarse lower division, which differs materially in composition from the sediments now laid down in the Potomac estuary; but since the abundance and size of the pebbles and bowlders now swept into the estuary are determined by the amount and thickness of the ice floated into it during the spring freshets, it is evident that the chief additional condition required for the deposition of the coarse materials of the older formation was diminution of temperature and consequent increase in floe transportation with, perhaps, concurrent strengthening of fluvial currents. It might accordingly be safely inferred from the phenomena of this tract alone that the lower member of the formation was deposited during a period of low temperature. The refrigeration thus suggested by the depos-

its of the Potomac river is proved by those of the Susquehanna and Delaware; and since the bowlders of the lower Columbia at Washington are fully twenty times as large and abundant as those brought down in the spring freshets of to-day, the diminution in temperature must have been considerable.

In brief, it is evident that the Columbia formation within the Washington amphitheater is a sub-estuarine delta deposited when the sea rose at least 150 feet higher, and the temperature was considerably lower, than to-day.

The Deposits on the Susquehanna.—About its locus of transition from fluvial to estuarine condition (for Chesapeake bay is simply the estuarine portion of the river), the Susquehanna is flanked by an extensive bipartite deposit, the upper member of which consists of loam with occasional disseminated pebbles and small bowlders, while the lower is a great mass of coarse sand and gravel interspersed with large bowlders. The distribution of the deposit, vertical and horizontal, is limited by the 240-foot contour, and it is typically developed only below the 120-foot contour; the most abundant materials of determinate source are bowlders from the Piedmont and Appalachian regions, and well-worn quartzite pebbles from the subjacent Potomac formation; the entire area is extensively terraced; and in general the phenomena duplicate those of the Potomac river. They are described in detail and fully illustrated elsewhere.*

Certain minor differences between the Susquehanna and Potomac deposits are noteworthy. The former reach far the greater volume, the thickness being thrice and the area twice as great as on the Potomac; the bowlders of the lower member are much larger—the largest being from 100 to 200 cubic feet in dimensions, or fully three times as large as those found on the Potomac and 50 times as large as those now transported into the bay in vernal ice-floes; the materials of the upper member are finer than on the Potomac, and consist in part of mechanically divided but undecomposed carbonate of lime, which either forms a calcareous cement or segregates into calcareous nodules resembling loess-kindchen; indications of iceberg action are found in the deposits; and a much larger proportion of the pebbles and bowlders of friable rock are sharply angular and evidently ice-transported. The resemblances between the deposits on the two rivers in structure and composition, in geographic and hypsographic distribution, and in all other distinctive characters, indeed, prove that they are homogenetic—i. e., that the Columbia formation on the Susquehanna

* "Notes on the Geology of the head of Chesapeake Bay," 7th An. Rep. U. S. Geol. Survey (in press).

as on the Potomac is a sub-estuarine delta laid down during a period of cold and submergence; and the differences prove that the submergence and the refrigeration were both the greater on the former river.

Above the fall-line the Susquehanna, unlike the Potomac, is flanked by deposits corresponding to the sub-estuarine delta. Between Columbia and its mouth, it is true, the river flows rapidly through a steep-sided gorge of considerable depth, the tributaries have high declivity, and superficial deposits are not preserved; but above Columbia the valley widens, its slope diminishes, and remnants of slack water deposits appear. Four miles above Harrisburg the river breaks through Kittatinny mountain in a widely-known water-gap, and embouches upon a slightly undulating terraced plain 100 to 200 feet above its level; and the prevailing superficial deposit over this plain is loam or brick clay passing down into a gravel or bowlder bed. A representative section of the prominent terrace half a mile northeast of Harrisburg is as follows:

1. Fine loam, massive above and horizontally laminated below, with a few disseminated pebbles and layers of sand toward the base, largely used as a brick clay ..... 7 feet.
2. Irregularly stratified gravel, comprising pebbles (commonly rounded) from 3 inches downward, imbedded in a matrix of coarse brown sand, the shale deeply ferruginated and sometimes cemented ..... 4 feet.
3. Stratified coarse brown sand abounding in pebbles and bowlders ..... 3 feet.

The three members are here sharply demarked, but elsewhere intergraduate.

Save that these deposits at Harrisburg are somewhat thinner, that the bowlders are smaller, and that they are without Piedmont crystallines, they are scarcely distinguishable from those about the head of Chesapeake bay. There is the same brick-red color, the same degree of ferrugination, the same bipartition and the same structure in each member, the same black ferruginous cement uniting and staining the pebbles, the same intergraduation of the members, and indeed so close similarity in all essential respects that either deposit might be accepted as the type of the other. And the deposits at Harrisburg are representative of those of a considerable area: the tract mantled with brick clay and gravel on the north side of the river below the Kittatinny water gap is 10 miles long and 5 miles wide, and the area of the deposits on the south side of the river is nearly as great. Above the water gap the deposits are still more largely developed; mile after mile the Susquehanna is flanked by gently sloping plains descending

nearly to the river and then dropping suddenly to its flat bottomed gorge, and everywhere except in the sharper ravines and larger tributary valleys the deposits prevail, and the altitude to which they rise progressively increases up the river; within its hypsographic limit the formation in the Susquehanna valley is nearly as continuous and distinctive as the glacial drift of the northern part of the state, and its influence upon the industries of its area is equally important.

The relations of these deposits to the terminal moraine and the relations of both to the topography are significant, and are well exhibited in the Susquehanna valley about Berwick and Bloomsburg. The broad features of the region, like those of the inter-montane Appalachian valleys generally, comprise old base level plains of considerable uniformity, bounded by mountain ranges, sharply incised by waterways cut down to a newer base-level. The principal waterway is the broad, steeply bluffed outer gorge of the pre-morainal Susquehanna. This gorge is partly filled with the overwash gravels from the moraine; and in these gravels the narrow inner gorge of the present river is excavated.

Three miles above Bloomsburg the old base-level plain is 5 or 6 miles wide, gently undulating, and 200 to 300 feet above the river, which follows its southern side (fig. 1). The entire plain is covered with a sheet of fine loam or brick clay similar to that of Harrisburg, and like it graduating downward into stratified sand or gravel containing well rounded bowlders of quartzite and other sub-local rocks up to a foot or more in diameter. On approaching the river this plain breaks down sharply in an abrupt escarpment, 75 to 100 feet high, overlooking the pre-morainal valley, the loam and gravel extending to the verge of the escarpment but failing below. This outer

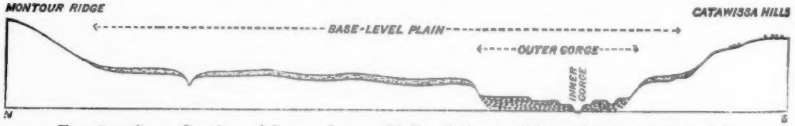

FIG. 1.—Cross-Section of Susquehanna Valley between Bloomsburg and Berwick.

valley of the Susquehanna is perhaps one and a half miles wide, and is lined to an undetermined but considerable depth with rounded pebbles and cobbles, sometimes interstratified with or overlain by fine gravel, sand or loam—the whole representing the overwash materials from the terminal moraine; and the valley bottom descends by step-like terraces of wonderfully sharp contour and fresh aspect to the narrow inner gorge within which the river tumbles and dashes over a bed of similar pebbles and cobbles. South of the river the surface rises

rapidly to the plateau-like summit of the Catawissa hills; and patches of loam similar to that forming the surface north of the river occasionally appear on the slope from 100 to 250 feet above the channel, and the hill-tops, 500 feet and less above the river, are dotted here and there with well rounded quartzite pebbles and bowlders two feet or more in maximum dimensions; the isolated loam patches and scattered bowlders alike representing residuary traces of a once continuous formation now largely removed.

The overwash gravels are stratigraphically continuous with and graduate imperceptibly into the terminal moraine, and are manifestly the product of a rapid glacier-born stream with considerable declivity. The loam of the base-level plain, on the other hand, is unquestionably a deposit of slack waters; but it contains a notable element of partly oxidized rock-flour (like that found at the head of Chesapeake bay), evidently of glacial origin. Moreover, the high-level bowlders at the base of, or incorporated within, the loam are much larger than those transported by the present river, and were evidently distributed by floating ice of greater thickness than that now formed in the same region. Both members of the formation thus attest contemporary climatal refrigeration.

As already indicated the high-level loam of the Bloomsburg-Berwick section is continuous—save where locally cut off by mountain ranges rising above its altitude—down the river to Harrisburg, and the residuary cobbles and bowlders occur at intervals over the slopes and within the inter-montane valleys from which the loam has disappeared: while the newer overwash gravels attenuate, their altitude diminishes, the materials become finer, the terraces merge and finally disappear, and the entire deposit fails above river level and the inner gorge is completely lost, about the confluence of the Western Branch at Northumberland. Traced up stream the loam and the residuary bowlders of the Columbia formation persist to the terminal moraine where the soft contours of the loam-mantled plain disappear beneath the knobby-surfaced moraine, and both loam and bowlders are incorporated in the moraine material; while the overwash gravels lining the outer valleys lose their distinct terracing, the cobbles increase in size and become less and less perfectly rounded, the materials become more and more heterogeneous until they too merge into the terminal moraine, and the entire valley is finally filled with aqueo-glacial gravels to a height of 250 or 275 feet above the present level of the river and to an unknown depth below.

While the gravel and cobble deposit is simply the overwash from the terminal moraine, the loam and high level residuary gravels evidently represent a distinct and far older formation:

the older deposit is bipartite, while the newer is indivisible; the loam of the older is unquestionably a slack water deposit, while the well rounded pebbles and cobbles of the newer were just as unquestionably assorted and deposited by rapid currents; the older deposit rises to altitudes of 500 feet above the level of the river, while the lower attains a maximum altitude of only 275 feet; the outer gorge of the Susquehanna has evidently been excavated in obdurate paleozoic rocks since the older deposit was laid down, while the work of the river since the deposition of the newer has been limited to the excavation of the far smaller inner gorge in unconsolidated gravels; the older deposit has been deeply dissected by the tributary waterways, and its slopes are softened and its escarpments rounded by weathering, while the same tributaries, despite their high declivity, have cut but trifling channels in the newer deposits, and the terrace scarps yet remain sharp-cut; the older deposit is everywhere deeply oxidized and ferruginated and its exposed bowlders of obdurate quartzite decolored and sometimes disintegrated, while the materials of the newer deposit are fresh and bright; and the older deposit everywhere passes beneath the terminal moraine into which the newer merges.

The relation of the loam and high level bowlders to the valley of the Susquehanna is significant. The river of the present is commonly unnavigable, and flows in a succession of rapids and intervening pools in a broad, shallow, rock-bottomed channel, with an average declivity of over two and one-half feet per mile: it is preëminently a transporting and corrading stream; and its local and temporary deposits are coarse. Yet the loam by which the valley sides are lined is evidently a deposit of slack waters, and the associated cobbles and bowlders appear to have been dropped from floes floating upon comparatively still waters; and the altitude of the deposits progressively increases northward. To produce such a change in the regimen of the Susquehanna as the Columbia phenomena indicate would require submergence of 240 feet at its mouth and fully 500 feet at the terminal moraine, and the transformation of its rock-bound gorge into an estuary, tidal to the Kittatinny water-gap at least.

The testimony of the Susquehanna phenomena corrborates and supplements that recorded in the Washington deposits, in that they are not only indicative of land submergence and coeval cold but prove (1) that the period of submergence was one of northern glaciation, (2) that this glacial epoch was long anterior to the one during which the terminal moraine was formed, and (3) that the submergence increased northward.

The Deposits on the Delaware.—As shown by the researches of Lewis and Chester, at Philadelphia and in northern Dela-

ware respectively, Delaware river and bay are flanked on the west from Philadelphia to Dover by a deposit of brick-clay or loam passing into gravel below—the Philadelphia Brick Clay and Red Gravel of the former author, and the Delaware Gravels of the latter. The deposits have been described in detail by these authors, and it will suffice to add that not only in general characters but in the less conspicuous features detectable on minute examination they are undistinguishable from their homologues in corresponding position on the Susquehanna and Potomac; the structure and composition are similar, the geographic and hypsographic distribution are alike, there is equal lixiviation and ferrugination, like ravining by erosion, the same extensive terracing, etc.; the only noteworthy difference being the somewhat greater altitude of the Delaware deposits, and the occasional presence of far transported northern pebbles and bowlders in their lower portion.

North of Philadelphia the Delaware deposits exhibit certain noteworthy characteristics allying them with those of the upper Susquehanna. Over the gentle river-ward slopes of eastern Montgomery and Bucks counties, Pennsylvania, more or less conspicuous accumulations of loam or brick clay occur up to altitudes of 250 feet or more; and well rounded bowlders occasionally appear at even greater altitudes. Within 100 feet above tide the deposits are practically continuous and extensively terraced—*e. g.*, there is at Trenton a sharply defined terrace 80 feet in altitude composed of homogeneous brick clay passing downward into a bowlder-bed, through which the Delaware has cut its modern gorge; and the celt-yielding Trenton gravels fill a basin lined with these older Quaternary deposits. Still farther northward the brick-clay or loam, with associated cobbles and bowlders, are found at progressively increasing altitudes; they occur in every inter-montane valley on the Delaware to the terminal moraine at Belvidere; and they are found on both sides of the Lehigh from its mouth to the water gap, the loam being largely utilized in brick manufacture at Allentown and elsewhere.

The cross-section of the Delaware valley five miles below Belvidere is in all essential respects a duplicate of the Bloomsburg-Berwick cross-section of the Susquehanna shown in fig. 1: there is the same loam-lined base-level valley 200 to 300 feet above the river, with scattered quartzite bowlders up to at least 400 feet; within this valley there is excavated, through loam and subjacent rock, an outer gorge at least a mile and a half wide; this outer gorge is bottomed with well rounded and current-sorted overwash gravels from the terminal moraine; and the sharply cut inner gorge of the present river, quarter of a mile wide and 50 feet deep, has been carved in the newer

gravels. To the northward the high level loam and bowlders pass beneath the terminal moraine, and the overwash gravels graduate into the hillocky debris of the drift-lined valley as on the Susquehanna; and as on that river too the overwash gravels rapidly diminish in size and abundance down stream, the terraces meantime merging and decreasing in height, until both practically disappear above water level 10 miles below Belvidere. Local accumulations of the overwash gravels occur, however, at various lower points on the river, the last and most conspicuous being at Trenton, where the later-glacial Delaware river opened into a broad estuary in which the vernal ice-floes dropped their debris gathered at the ice front.

On the Delaware, as on the Susquehanna, the two series of superficial deposits—the moraine with its derivatives and the terraced brick clay with its gravels—are perfectly distinct and widely diverse in age; and here, too, the deposition of the loam and high level gravels must have been accompanied by transformation of the Delaware river from a rapid unnavigable stream abounding in cascades and rapids, to a tidal estuary miles in width within which fine silt and clay were dropped, and upon which bowlder-bearing ice-blocks floated—the land-submergence reaching fully 400 feet in the latitude of the terminal moraine.

The Deposits on other Rivers.—Every considerable stream of the Middle Atlantic slope has at the fall-line a conspicuous deposit analogous to those of the Potomac, Susquehanna, and Delaware; and while the deposits vary in volume with the streams, the structure, the composition, the geographic and hypsographic relations, etc., remain constant or change slowly with latitude. The Schuylkill and Brandywine deposits merge into those of the Delaware, but in their up-stream extension are distinguishable therefrom by the abundance of local and the sparseness of northern materials; the deposits of Elk and Northeast rivers are distinguishable from those of the Delaware on the one hand and of the Susquehanna on the other by the preponderance of local materials, and at low levels by their independent terrace systems; the Patapsco deposits merge into those of the Susquehanna at Baltimore, but local pebbles in the lower member and the preponderance of local residuary debris in the upper give individuality to the Patapsco delta, which in structure, composition, and general aspect, is undistinguishable from that of the Potomac river at Washington; the two branches of the Patuxent have beautifully terraced deltas exhibiting characteristic bipartition and all of the diagnostic features of the fluvial phase of the Columbia formation; and the Anacostia has an independent but homologous system of deposits and terraces made up predominantly of materials derived from the marginal portion of the Piedmont area.

South of the Potomac river the deposits and terraces remain conspicuous,though their maximum altitudes diminish: Occoquan river, Acquia creek, and neighboring streams have well-marked terrace-systems built of deposits of uniform structure, though each deposit is made up of the materials traversed by the individual stream; the Rappahannock valley is fashioned into terraces miles in extent and flanked by brick clays passing into gravel and bowlder beds made up of the Piedmont rocks and well-rounded gravel derived from the adjacent Potomac beds, the whole resembling the delta of the Potomac river so closely that a typical section in one would equally represent the other; the Taponi and the Mat have corresponding deltas which unite and flank the Mattaponi for miles, and the two Anna rivers exhibit similar deposits of greater volume merging along the Pamunkey; the superficial deposits about the head of tide in James river are so similar to those of the Potomac that Plates VI and VII could be almost exactly duplicated there, though the area of the delta is somewhat greater and its altitude somewhat less than that of the latter river; the Appomattox has its elevated delta which merges into that of the James, but is distinguished in the vicinity of Petersburg by an independent system of terraces and by the preponderance of local rocks; the Nottoway and Meherrin also exhibit well-developed deposits of the usual bipartite structure, as do the smaller streams, Rowanty, Stony, and Fontaine; and finally the Roanoke embouches from its narrow Piedmont gorge into a tidal estuary flanked by low bluffs built of or capped by the prevalent brick clay and gravel with local bowlders.

The maximum altitude of the deposits, which is 500 feet on the Susquehanna and 400 feet or more on the Delaware, diminishes southward to perhaps 275 on the Schuylkill, 245 at the mouth of the Susquehanna, 145 feet (with inconspicuous deposits somewhat higher) on the Potomac, 125 feet on the Rappahannock, 100 feet on the James, and 75 feet on the Roanoke; and as already pointed out,* the maximum size of the bowlders in the lower member, as compared with those now transported by the rivers, diminishes from 50:1 on the Susquehanna to 20:1 on the Potomac, 10:1 on the Rappahannock. 5:1 on the James, and 2 or 3 times the present volume on the Roanoke.

Recapitulation.—Briefly, the deposits along the Middle Atlantic slope rivers about their loci of transition from fluvial to estuarine condition are so closely similar that not only will the description of a typical section on one waterway apply to those of all the others, but it would in most cases be difficult to determine from the most minute examination which stream

*This Journal, III, xxxiv, 219, 1887.

a particular specimen or section represents; the differences are limited to systematic variation in altitude and coarseness, to variation in volume (which is proportional to that of the streams on which the deposits occur), and to inconspicuous variation in composition resulting from the incorporation of (1) local materials on each river, and (2) rock-flour and other glacial debris on the more northerly rivers. The deposits are evidently contemporaneous and homogenetic; the structure, composition, geographic and hypsographic distribution, terracing, and other features of each independently proves that it is a sub-estuarine delta formed during a brief period of land-submergence and refrigeration, increasing northward; and the relations of the various deltas to the terminal moraine and other deposits prove that this period was long anterior to that of the last ice-invasion.

The Interfluvial Phase.—Character and Distribution.—The fan-shaped deltas flanking the Middle Atlantic slope rivers at the fall-line attenuate down stream and toward their peripheries, and either disappear in feather edges along ascending slopes, or merge into a distinctive deposit by which the interfluvial portion of the Coastal plain is generally mantled. .This deposit, unlike the complementary and more conspicuous one developed only along the rivers, is variable in composition and inconstant in structure, and has a wide range in hypsographic distribution. Four leading structural types, ranging in altitude from 100 feet in the south to 400 feet in the north down to tide level, may be discriminated.

1. As exposed in the terraces and shore lines in the vicinity of the fall-line, the deposit consists of a heterogeneous and irregularly bedded mass of sand, gravel and bowlders fringing the terrace, and increasing in thickness from perhaps a foot or two upon the terrace plain to five, ten, or fifteen feet along the scarp; the materials being predominantly local, and evidently derived largely from contiguous portions of the terrace-plain but intermingled with loam, pebbles and bowlders similar to those of neighboring deltas. Similar accumulations occasionally fill old ravines and other depressions in the formerly irregular surfaces now smoothed into terrace-plains. This type of the deposit is well exhibited in the scarp of an extensive terrace near Washington (in a cutting on the Falls Church road), and in the cuttings in the northeastern part of the same city on Benning's road; but such exposures are common, and those observed and noted between the Roanoke and the Delaware are numbered by scores. They frequently occur above the maximum altitude of the fluvial phase of the formation in the same latitude.

2. A second type is exhibited only in northern New Jersey

and on the marginal portion of the Piedmont zone at altitudes reaching 250 feet or more. It consists of great beds of well rounded quartzite cobbles a foot or less in diameter, together with many smaller pebbles, generally imbedded in reddish loam. A representative locality is the plateau (100 to 150 feet above tide) between Harlingen and Rocky Hill and five or six miles north of Princeton, where, over an area of several square miles, well rounded quartzite cobbles cumber the fields and are heaped up along the lanes in great winrows sufficient to fence the farms and pave the roads.

3. The type of the deposit into which the deltas commonly merge is a confused and heterogeneous mass of sand, gravel, and pebbles of obscure or inconstant structure, the materials evidently derived in larger part from the sub-terrane and in smaller part from the contiguous deltas, and the thickness ranging from a foot or two to perhaps fifteen or twenty feet. In the south the materials are predominently fine, comprising sand, clay and silt interspersed with occasional pebbles up to three or four inches in diameter, with a few intercalated sheets of gravel; while in the north the deposit is predominently coarse and gravelly, especially toward the northern extremity of the Coastal plain where it has been recognized by Cook, Lewis and Chester as "Southern Drift," "Yellow Gravel," "Delaware Gravels," etc.; and in a general way it varies in coarseness and in thickness from the fall-line to the coast, the thickness increasing and the coarseness diminishing seaward. This is by far the most extensive type of the deposit; it covers perhaps three-fourths of the area of the Coastal plain; but despite its vast extent, good exposures are uncommon. Those at Ordinary Point on Sassafras river, in northern New Jersey, and on Long Island (described elsewhere by the writer, Cook and Merrill, respectively), are, however, representative of the latitudes in which and the altitudes at which they occur.

4. At low levels, especially along the coast, the deposit becomes fine, assumes moderately regular stratification, attains considerable thickness, and yields recent fossils. This type has been described by W. B. Rogers in eastern Virginia, Tyson in peninsular Maryland, Booth and Chester in southern Delaware, Conrad in New Jersey and southern Maryland, Merrill on Long Island, and others in different localities, and does not require extended notice here.

Summarily, the interfluvial phase of the formation consists of a mantle of either heterogeneous or definitely assorted and deposited material, largely local but partly erratic, overspreading the Coastal plain (except along the water ways), from the Roanoke to the Raritan, and encroaching upon the Piedmont

region in the north; this general mantle merges into the elevated deltas of the fluvial phase on the one hand, and into the modern alluvial, estuarine and marine deposits on the other; and it is either buried beneath or broken up and incorporated within the terminal moraine in its northward extension.

Sources of Materials.—The prevailing materials of the deposit may be roughly classed as (1) well rounded cobbles and pebbles, such as those of northern New Jersey; (2) well rounded quartz and quartzite gravel, such as overspreads peninsular New Jersey; (3) fine gravel and sand, clean or intermixed with clay or silt, forming a matrix in which the coarser materials are imbedded, and constituting the great bulk of the deposit, particularly in the south; (4) loam, resembling that of the upper division of the fluvial phase, and exemplified by the high level red loams of northern New Jersey and southeastern Pennsylvania; and (5) clay and silt, generally stratified and limited to low altitudes. The sources of the first two of these classes are precisely, and those of the next two proximately, determinate.

1. The cobbles of northern New Jersey are in form and material identical with, and in size generally smaller in a graduating series than, the high level bowlders of the fluvial phase along the Delaware; both are identical lithologically with the axial quartzites of the southeasternmost Appalachian ranges; and both cobbles and bowlders not infrequently contain fossils identical with those of the quartzite ridges. The erratics, it is true, are commonly more profoundly metamorphosed than the parent ledges; but they obviously represent the most obdurate portions of these ledges, and moreover examination shows that in many cases the metamorphism is superficial and produced by interstitial growth after the manner described by Irving, while the interior remains in the same condition as the quartzites now found *in situ*. Some of these cobbles doubtless formed originally a part of the Potomac formation, and were removed from it and redeposited during the Columbia epoch; but others appear to have been derived directly from the quartzite ranges whose bases were washed by the floe-bearing Columbia waters, and whose ledges were shattered by the Columbia cold. Certainly the angular blocks now cumbering the upper mountain slopes, and the smaller and well-rounded cobbles imbedded in the Columbia formation, are but the extremes of a graduated series whose continuity can be readily traced along either the Delaware or the Lehigh.

2. Save that its average size is slightly smaller, the well-rounded gravel of peninsular New Jersey and the Maryland-Delaware peninsula is identical in all physical characters with that of the Potomac outliers skirting the Piedmont escarp-

ment from the James to beyond the Schuylkill; there is not a fossil nor a rock-variety in one that cannot be duplicated in the other; the materials are sometimes absolutely undistinguishable in hand-specimens or in extensive sections except by general structural features; and in some cases the high-level gravels of the Potomac outliers may be traced continuously into the low-level gravels of the Columbia. The lower member of the Potomac formation is the great gravel source of the Middle Atlantic slope, and has furnished materials for upper Potomac, Cretaceous, Eocene, and Miocene gravel beds; but during the Columbia period of delta-deposition the waves of the ocean beat upon its unprotected outliers between the Rappahannock and the Raritan, and especially between the Susquehanna and the Delaware, and its contributions were larger than ever before. By petrography, by paleontology, by structural continuity, and by physiographic relations, it is proved that the source of the mysterious gravels of the northern Coastal plain are derived from the Mesozoic gravel-heaps of the adjacent Piedmont margin.

3. In a general way the fine gravel and sand may be traced by petrographic similarity to the immediate sub-terrane and to the terranes traversed by the nearest great water-ways; and in some cases—*e. g.*, where they consist of redeposited Potomac arkose with little admixture of foreign matter—the exact source may be ascertained.

4. The amount of loam found in any part of the formation is roughly proportional to the proximity of deltas; and its origin is evidently the same as that of the predominant element in the upper division of the fluvial phase of the formation, *i. e.*, it is redeposited residuary debris from the Piedmont region.

5. The clays and silts appear to be made up of the finest and farthest-transported debris from rocks *in situ* and from the coarser materials, both local and erratic.

Genesis.—It is impossible to convey definite conceptions of geologic structure or topographic configuration by verbal description; and it is impracticable to prove the sub-aqueous origin of the interfluvial phase of the Columbia formation by mechanical reproduction of structural aspect, as in the fluvial phase; but neither is necessary (1) since the sub-aqueous deltas of the fluvial phase graduate into and are stratigraphically continuous with the interfluvial phase, (2) since marine fossils have been found within it by a dozen eminent geologists and paleontologists (enumerated later), (3) since no other agency or agencies known to geologic science are competent to produce such deposits, (4) since its margin is marked by unmistakable shore-lines and beaches, and (5) since every geologist who has ever investigated any considerable part of the formation, including

Lyell, Mather, the Rogers brothers, Tuomey, Desor, Conrad, Booth, Tyson, Kerr, Fontaine, Cook, Lewis, Chester, Merrill, Britton, and others, has recorded the conviction that such part at least was waterlaid. The physiographic relations of the phenomena and the area over which they prevail are such that the evidence of sub-aqueous origin is cumulative, and now that definite observations have been extended over the greater part of the area it can only be regarded as decisive; the coarseness of the northern deposits as compared with the southern, and the occasional presence of evidently ice-dropped bowlders indicates that the period of submergence was one of refrigeration; and the limited volume of the formation indicates that the period of deposition was short.

So the interfluvial deposits corroborate and extend the testimony of the deltas; and the phenomena conjointly record a brief period of submergence of the entire Coastal plain in the Middle Atlantic slope reaching 100 feet in the south and over 400 feet in the north, with coëval cold, long anterior to the terminal moraine period.

The Terraces and Shore Lines—Every Middle Atlantic slope river embouches through a narrow gorge in the Piedmont escarpment into a widely flaring shallow valley partly occupied by the estuarine portion of the river; and each of these valleys is notably terraced. The city of Weldon is located on a broad terrace of the Roanoke sixty feet above its tidal waters; Petersburg is built upon two or three distinct terraces flanking the Appomattox, of which one is 110 feet in altitude and many miles in extent; the higher portions of Richmond, including the public park, are located upon an extensive terrace overlooking James river from a height of 180 feet above tide on the north, while another terrace eighty feet in altitude has an area of at least twenty-five square miles on the south side of the river; the terraces on the Rappahannock at Fredericksburg are as distinctive and more extensive than those of the lacustral basins of Bonneville and Lahontan, as are also those about Washington; the valleys of the Patuxent and Patapsco, of the Susquehanna, and of the Brandywine and Schuylkill, exhibit wide reaching series of terraces of progressively increasing altitude; at Trenton the Delaware has cut a narrow gap in an otherwise continuous terrace of brick clay and gravel of great extent and uniformity, and through that gap the Trenton gravels have been swept; and at Metuchen, N. J., wonderfully broad terraces extend to the very base of the hillocky terminal moraine, which has evidently been pushed out upon their plains.

While the best developed terraces about the mouths of the rivers form independent systems, the higher members fre-

quently extend across the divides from river to river. Thus between the Roanoke and the Appomattox the highways traverse sensibly horizontal plains, only broken at long intervals by the low steep scarps of terraces, or by the narrow steep-sided ravines incised within them, the plains being of such extent as to yet remain imperfectly drained. The same is true of the low plateau between the Appomattox and the James, and of the greater part of the country between the James and Rappahannock. North of the Rappahannock the high level terrace-plains become less conspicuous as the shore line rises from the friable clastics to the firm crystalline terranes, but considerable plains occasionally occur; and between the Schuylkill and the terminal moraine beautiful terrace-plains of wide extent are carved out of the Triassic sandstones up to altitudes of nearly 200 feet. The terraces are best developed along the inland margin of the Columbia formation, but reach somewhat greater altitudes, ranging from about 100 feet in the south to more than 400 feet in New Jersey.

Though most prominent along the fall-line, the terraces are not confined to it, but occur at intervals over the entire Coastal plain, their extent and perfection depending upon the materials in which they are carved or from which they are built, and upon the erosion they have suffered. Thus in eastern Maryland it is possible to approximately map the western boundary of the greensands by the perfection of the terraces —the firm clays to the westward being everywhere distinctly terraced, while the more friable sands have assumed the characteristic undulating surface happily designated "topographic old age" by Chamberlin.

In brief, there is a practically continuous series of terraces and beach marks along the fall-line from the Roanoke to the terminal moraine—a series of shore lines as distinctive and unmistakable as those circumscribing the valleys of the extinct lakes of the Great Basin, of India, of northern Arabia, or of the partially ice-bound basins of Minnesota, Michigan, Ohio and New York, though they are generally more profoundly modified by erosion and are frequently concealed by forests. These shore lines embody an easily interpreted record of geologic vicissitude which coincides in every detail with that of the Columbia deposits. They are sometimes carved out of the sub-terrane but are generally built of the loam, sand, and gravel of which the Columbia formation consists, and are evidently coëval therewith. Now it is manifest that these terraces are water fashioned; but they are not fluvial. There is always a vertical component in fluvial action, and the energy of the action varies with the value of this component; every alteration in the course of a wandering stream means change in

declivity, and every change in declivity means modification in competence and variation in deposits. So fluvial deposits are heterogeneous. Moreover rivers take the paths of least resistance and flow freely in deep channels, and in selecting their courses they avoid the higher levels and seek depressions which they continually deepen; the deeper the initial depression the more rapidly is it deepened; and thus fluvial action ever accentuates irregularity of surface. So fluvial plains are multiform. But the forces concerned in the formation of the Middle Atlantic slope terraces acted horizontally over great distances and with uniform energy for a considerable period, filling depressions, softening contours, and obliterating relief, yet so gently that essential homogeneity of deposit in the horizontal direction and essential uniformity in surface prevails for miles. Only the undulatory and horizontally acting force of waves appears competent to produce so great expanses of uniform surface and constant structure as are exhibited in this region

By the testimony of terraces and shore-lines the existence of inland seas and lakes of Quaternary age in many portions of the world has been proved to the satisfaction of geologists; yet although the middle Atlantic slope terraces have been more deeply graven by erosion and reduced by weathering, they are more extensive than those of any of the extinct or shrunken Quaternary lakes in the country; and their testimony is equally decisive.

[To be continued.]

Art. XXXII.—*On some peculiarly spotted Rocks from Pigeon Point, Minnesota;* by W. S. Bayley.

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The northeastern extremity of Minnesota is known on the charts as Pigeon Point.* This point extends in an easterly direction into Lake Superior. It is separated from Canada by the waters of Pigeon Bay and Pigeon River. Its length is about three and a half miles. Its width varies from a few hundred feet to a little less than half a mile. The greater portion of its mass consists of a great dyke of coarse olivine gabbro† or diabase. Associated with this is a large quantity of

* The exact location of the point is T. 64 N., R. 7 E. of the 4th principal meridian, Sections 25, 26, 27, 28, 29, 30, 31 and 32.

† Cf. Irving: Copper-Bearing Rocks of Lake Superior, Monograph V, U. S. G. S. Washington, 1883, p. 369 et seq.

bright red drusy granite, whose relations to the gabbro have not yet been satisfactorily determined. To the south of these eruptive rocks, on the Lake Superior side of the point, is a narrow strip of slates and quartzites, which dip to the southeast at an angle of 15°–20°, and are cut by numerous diabase dykes. According to Irving* these slates and quartzites belong to Hunt's Animiké series and are Huronian in age. Upon their contact with the eruptives these fragmental rocks lose all traces of sedimentary origin. Under the microscope they are seen to have undergone extreme metamorphism. Whether this consists in a mere recrystallization of the material already existing in them, or in a recrystallization with the addition of new substance derived from the eruptive rocks, or in a complete solution of their fragments in the latter must be left for further study to decide.

The object of the present paper is to describe certain peculiar spots noted on the quartzites in a few localities and to discuss briefly their origin.

The quartzites in their unaltered forms comprise evenly bedded light gray, pinkish and black varieties. These are all very compact and hard, and have the vitreous appearance characteristic of indurated quartzites. They are cut by joint cracks running in a north and south direction and standing nearly vertical. The sides of these cracks are usually covered with little quartz crystals. Under the microscope the darker varieties are seen to consist mainly of round and angular pieces of quartz, in a groundmass of interlocking silica, which under crossed nicols is resolved into small areas optically continuous with the original grains to which they are attached.† Decomposed orthoclase, colored red by minute plates of hematite and iron hydroxide, a very little plagioclase, sometimes fresh but more frequently much altered, little flakes of brown biotite, chlorite, and grains of magnetite and earthy iron minerals constitute the balance of the rock. In the lighter varieties the plagioclase is more abundant and the chlorite much less so. In the pinkish varieties reddened orthoclase and plagioclase make up about half of the entire rock.

In certain restricted areas on the south shore of the point, notably in the western half of section 25 and in the southeast quarter of section 32, curious circular spots are developed on the surface of the quartzite. These spots vary in size from less than a quarter of an inch to over two inches in diameter. On a weathered surface they appear as slight depressions surrounded by a raised rim of a lightish brick-red color. Their distribution

* This Journal, xxxiv, 1887, p. 262.

† Cf. Irving and Van Hise: Bulletin of the U. S. Geol. Survey, No. 8, Washington, 1884.

is very irregular. Frequently a single spot stands alone. Sometimes two or more spots are united, and when this is the case one rim encloses the group. Figure 1 represents the shape and general appearance of some of these groups as seen on a smooth weathered surface.

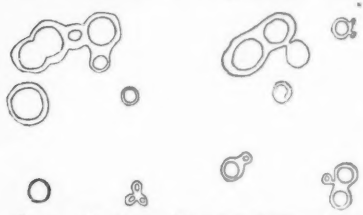

Fig. 1. About one-third actual diameters.

When the rock bearing such spots is broken it is observed that the bodies producing them are themselves either lenticular in shape or spherical. They possess a sugary texture and are of a pistachio green color. When moistened with hydrochloric acid they effervesce with a slight evolution of gas. Like the circles on a weathered surface these spheroidal bodies are also surrounded by a narrow brick-red rim. The rims are here fairly well defined against the substance which they enclose, but on their outer edges gradually shade off into the body of the rock.

Associated with these spotted rocks, but at a greater distance from the eruptives, are other quartzites which show no spots on a weathered surface, but which contain little concavities with diameters of about the same magnitude as those of the spots mentioned above. On a fresh fracture of these, instead of the green spheroidal bodies, are circular and oval areas, which reflect the light evenly, as from a smooth cleavage surface, and show a silvery luster. When treated with acids they effervesce very briskly. They are nothing more than concretions of calcium carbonate so often met with in the slates and sandstones of many regions.*

Under the microscope the body of a specimen of one of these rocks (No. 11,461 of the collection of the Lake Superior Division U. S. Geological Survey) is seen to be composed of an aggregate of quartz, feldspar and green mica. The quartz is in rounded grains, which everywhere show secondary enlargement. Much of the feldspar is triclinic. The green mica is slightly pleochroic and seems to have crystallized in position. A few grains of magnetite are scattered through the section, and small areas of calcite are occasionally found enclosing the other constituents. The silvery spots consist of perfectly transparent calcite. This encloses all the other constituents, which are the same as those found in the main portion of the section. It polarizes in large areas, although several of these are seen in a single spot.

* Ct. Tschermak: Lehrbuch der Mineralogie, Auf. II, p. 117.

The rocks immediately associated with the spotted rocks in the same beds, but which themselves are free from spots, differ but slightly from the last described rock in structure. They contain, however, quite a large quantity of chlorite, which has clearly been derived from biotite on the one hand, and from feldspar on the other. Closely intermingled with this, but more particularly in the neighborhood of little calcite nests numerous irregularly shaped plates of a light green, strongly pleochroic and brightly polarizing epidote are frequent. In most cases however the epidote occurs in tiny rounded grains and rudely outlined crystals scattered everywhere throughout the feldspathic and chloritic groundmass in which the enlarged quartzes are imbedded. These little particles are sometimes crossed by cleavage cracks parallel to which extinction takes place. They have a faint greenish tinge and a very high refractive index. In addition to chlorite and epidote the rocks of this class sometimes contain flakes of brown biotite, magnetite and calcite.

The groundmass of the spotted rocks when examined under the microscope, presents the same features as are observed in the epidote-bearing rocks just described, except that the epidote grains are much less abundant and in some cases are almost entirely lacking.

The spots, on the contrary, are usually very rich in epidote. They consist of enlarged quartz grains, a little feldspar and occasionally a small quantity of chlorite, all imbedded in a mass of calcite and epidote. The amount of calcite present varies within wide limits. It sometimes occupies nearly the entire space between the quartz, feldspar and chlorite to the almost complete exclusion of the epidote. In other cases it occurs only sparingly, while the epidote is massed in little plates, grains and crystals. Only rarely were well terminated crystals observed (No. 11,463). These average $\frac{1}{25}$ of a millimeter in length. A few forms are represented in figure 2. Although but very slightly pleochroic, the true nature of the crystals cannot be doubted. In color they are of such a very pale green tint as to be almost colorless. They possess a cleavage and an extinction parallel to their long axes, have a high index of refraction and are usually free from inclusions. They are distinguished from sahlite, which they closely resemble, by the fact that the plane of their optical axes is at right angles to their cleavage.

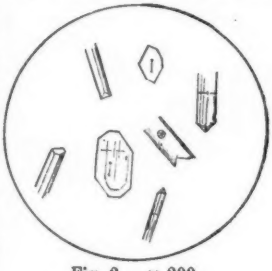

Fig. 2. × 200.

Around the spots are clear zones corresponding to the raised rims, mentioned as surrounding the hollow interiors of spots on a weathered surface. These zones are sometimes composed of grains and plates of epidote larger than those found in the interior of the spots, either with or without calcite. When epidote is present in the rims there is a scarcity of this mineral in the interior of the spots. This is the rule in those rocks which contain a large amount of altered feldspar and chlorite. In these feldspar, quartz, chlorite, a little bleached biotite, little plates of hematite and grains of magnetite constitute both the interior of the spot and the body of the rock. In the spot the chlorite is better crystallized than elsewhere. The rim contains only quartz, calcite and epidote, except on its outer edge, where there is an accumulation of red oxide of iron. In those cases in which the interior of the spots contains a large amount of epidote, the exterior zone is comparatively free from this mineral, consisting essentially of quartz and feldspar stained red by iron oxides. In both cases chlorite is absent from the rim.

Although each specimen of these spotted rocks, when examined under the microscope, presents features peculiar to itself, it is unnecessary to describe them all. It is sufficient to have called attention to their most striking characteristics, and to have mentioned merely those features common to the class. The incidental peculiarities due most probably to slight differences in the original composition of different parts of the beds have been neglected.

The occurrence of the spots in well defined beds lying between those which contain no spots, would at once lead to the supposition that they owe their origin to the existence in these beds of some substance, which was absent from those containing no spots. The shape of the spots and their groupings suggest concretions. Epidote is not known to occur in such forms in fragmental rocks, while concretions of calcite are common. The existence of such calcite concretions in the unaltered rocks of Pigeon Point is clearly established in the one instance mentioned above (No. 11,461). Here we have a quartzite differing in no wise from similar quartzites occurring at a distance from the eruptive rocks, except in the possession of calcite concretions. Nearer the eruptives, whether these be granite or diabase, are other quartzites containing a little more well individualized chlorite and large quantities of epidote. This epidote is closely associated with calcite, the latter increasing with the decrease of the former, and the two being always bounded by the outlines common to concretionary bodies in sedimentary rocks. As the result of a large number of studies upon limestones which have been altered in the

neighborhood of eruptive masses it has been found that epidote* is one of the most common of the new minerals produced. Moreover it is known that in these cases of limestone metamorphism the eruptive rocks have added but little, if any, of their substance to the intruded rock, except perhaps silica. Their principal agency in the production of contact phenomena has been heat. The percolation of silica-bearing solutions through calcite-bearing sedimentaries was alone not sufficient to produce the crystallized epidote described above. This is evident from the existence of epidote-free calcite concretions in rocks occurring at some distance from any eruptive mass, while at the same time these rocks are typical indurated quartzites in which all the quartz grains have been enlarged by the deposition of secondary silica around them (No. 11,461). There was no necessity for the addition to these concretions of any material from the eruptive rocks in order to change them into epidote. They already contained the elements essential to the formation of this mineral. These merely needed an opportunity to arrange themselves in the form of epidote—a very stable compound under the conditions prevailing during contact metamorphism, as so many investigations have shown. This opportunity, it is believed, was afforded by the appearance of the eruptive masses. The epidotic rocks and spotted quartzites are always found in close proximity to masses of eruptive origin. They moreover contain large amounts of newly developed chlorite, a result which may likewise be ascribed to contact action. It would seem, then, that we are justified in regarding these epidotic rocks, particularly the spotted varieties, as the result of the action of the intrusive rocks, upon the sedimentary beds through which they forced their way from beneath.

Where calcite was scattered in little nests through the mass of the fragmental rocks, epidote is now found in similar relations to the other constituents. Where the calcite was present in spheroidal concretions enclosing quartz grains, feldspar, chlorite, etc., there now occur little spheroidal bodies consisting in large part of crystals of epidote. The hard envelopes around these spheroids appear to owe their power to resist weathering principally to the lack of chlorite in their composition.

In closing I would acknowledge my obligations to Dr. Geo. H. Williams of the Johns Hopkins University for valuable suggestions offered during the earlier portion of this study.

January 19, 1888.

* Cf. J. Roth: Allgemeine und chemische Geologie, Bd. i, p. 428 et seq.; and Rosenbusch: Mikroskopische Physiographie, 1885, Bd. i, p. 498.

ART. XXXIII.—*The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature;* by CHAS. D. WALCOTT, of the U. S. Geological Survey. With Plate III.

(Continued from page 327.)

NOMENCLATURE.

I. Use of the name Taconic. II. Use of the name Cambrian. III. Classification of North American Cambrian rocks.

Use of the name Taconic.—To the writer the evidence presented and referred to in the preceding pages proves that the "Taconic System" was founded on errors of stratigraphy of such character and magnitude that the name Taconic has no claim upon the geologist for recognition in geologic nomenclature.

I endeavored to make, in 1886, an argument for the use of the name Taconic for the Middle division of the Cambrian System, but it failed in the light of later results of field work; and now I think that geologic nomenclature will be benefited by dropping the name entirely. Based on error and misconception originally, and used in an erroneous manner since, it serves only to confuse the mind of the student, when applied to any formation or terrane. There are several reasons for the foregoing conclusions that perhaps it is best to here state:

1st.—The name is not applicable. The Taconic range, from which the "Taconic System" was named, is not known to contain a fossil of the First fauna or a formation that contains one elsewhere. The "Upper Taconic" slates lie west of the range, and the "Granular Quartz" series east of it; and the range is formed of strata of the Trenton-Hudson Terrane.

2d.—The "Taconic System" was considered pre-Potsdam, on two suppositions: (*a*) that the Calciferous sandrock of the Lower Silurian is unconformably superjacent to the Taconic slates, on the west; (*b*) that the variation of the lithologic characters of the Lower Taconic rocks, from the New York Lower Silurian, indicates a distinct system of rocks. We find that the unconformity (*a*) was based on errors of field observation, and (*b*), that the "Lower Taconic" rocks are of Lower Silurian age, with the exception of the lower quartzite, which is Cambrian and *conformably* subjacent to the Lower Silurian.

3d.—The claim of priority of discovery of the Primordial fauna is invalidated by the fact that the fossils found in the Taconic slate were referred to a pre-Potsdam horizon on an erroneous interpretation of the stratigraphy and not from comparison with a known fauna that had been stratigraphically located in any clearly defined geologic section.

4th.—It is only a fortunate happening, and not a scientific induction based on accurate stratigraphic or paleontologic work, that any portion of the "Taconic System" is found to be where Dr. Emmons placed it.

5th.—The application of the principles stated at the beginning of this paper rules out the name Taconic from geologic nomenclature.

6th.—The term Cambrian antedates Taconic for a stratigraphic system and, also, as a correctly-defined faunal definition.

It was stated under "Discussion" that Professor Dana held the opinion that the "Lower Taconic" was the typical "Taconic System," as first defined in 1842, but as that was proven to be Lower Silurian in age, the "Taconic System" could not longer be recognized.* For a time I was inclined to disagree with this view, but as I approach the end of this investigation I am convinced, after a full consideration of all the circumstances, that the position taken by Professor Dana is the correct one.

The first published section of the "Taconic System" gives *all* the rocks included within it in 1842.† The gneiss is represented on the extreme east and the "Taconic slate" on the extreme west and the "shales of the Champlain group" as resting unconformably on the "Taconic slate." This section includes *all* the strata of the "Taconic System," as then known to Dr. Emmons, and agrees with the description, in the accompanying text, of the rocks of the System.‡

Five additional sections are given on Plate XI, four of which are in the typical area and agree with the section in the text (loc. cit., p. 145, fig. 46). The latter section and the first four sections of Plate XI do not extend west of the area of Hudson slate on the line of Hoosick Falls in Rensselaer Co., N. Y. (see map). They all limit the "Taconic System" at this belt of the Hudson Terrane, and the accompanying text corroborates the view expressed in the sections. A glance at the map shows that not one single outcrop of rock of the "Upper Taconic" was included in the "Taconic System," as originally proposed, with the exception to be noted of Section 5, Plate XI, and not until 1887 was it proven that any portion of the original Taconic System was older or subjacent to the horizon of the Potsdam sandstone. As is mentioned in the 1st reason given for rejecting the name Taconic, there is not a known stratum of rock in the Taconic range that is of the geologic

* This Journal, III, vol. xxxi, pp. 241–244, 1886.

† Geol. N. Y., pt. 2, p. 145, fig. 46, 1842.

‡ Loc. cit., pp. 144, 145.

age assigned to it by Dr. Emmons. In 1844 he incorporated a great series of slates and shales belonging to another geologic system by extending his sections across the western belt of the Hudson Terrane, that limited the section of 1842, and on west to the next line of outcrop of Lower Silurian rocks. This addition gave the opportunity to separate off the "Upper Taconic" in 1856. I have shown that all his reasons for calling this series pre-Potsdam were based on errors of stratigraphy; and that it was a fortunate happening that any portion of the "Upper Taconic" rocks occur where he placed them in his stratigraphic scheme. Even if there were no errors to vitiate Dr. Emmons's argument for the pre-Potsdam position of the "Upper Taconic," that portion of his system could not retain the name "Taconic;" for it belongs to a different stratigraphic system from that to which the strata of the Taconic range belong and to which he gave the name "Taconic."

Section V, of Plate XI, represents a section of strata a few miles south of Burlington, Vt., and includes, not the "Taconic System" of the first five sections and the text by Dr. Emmons in 1842, but strata entirely disconnected from the original Taconic, which, nineteen years later, was proven to belong in part to the "Upper Taconic." This section is not mentioned in the text, but it is evidently considered as exhibiting the same relative geologic section as the other sections, a view that is substantiated by the name "Taconic slate" being given to the strata referred to the "Taconic System." There is not any stratigraphic connection between the Vermont section (No. 5) and the sections in the Taconic area (see map), and until 1859 there was not any paleontologic evidence that the slates of section 5 were or were not of the same geologic age as the "Taconic slates" of the five other sections and the text. In 1859 the publication of the Olenellus fauna by Professor Hall, proved that Dr. Emmons was mistaken in referring the Vermont slates, of section 5, to his Taconic System of 1842. I do not think that we can admit as evidence in favor of the strata of the "Upper Taconic" having been described in the original work of 1842, such an erroneous identification of a section that had at the time no stratigraphic or paleontologic connection with the original Taconic System.

It was not until the field work, in the fall of 1887, was concluded that I arrived at the above conclusions. Professor Dana reached it long before, and Dr. T. S. Hunt holds that the "Lower Taconic" is the typical Taconic. It matters not whether geologists agree to restrict the test of what the original Taconic was to the original Taconic of 1842 or hold that Dr. Emmons had the right to add the strata separated off into

the "Upper Taconic" in 1856, the name Taconic does not appear to have any place in the geologic nomenclature of to-day.

The following tabulation of the successive phases of the Taconic system viewed in the light of present facts is instructive. It was proposed in a letter from Professor Dana to the writer:

PHASE I, 1842.

*	"Taconic System"	True order begins.	
	6. Stockbridge limestone	II.	Lower Silurian limestone.
	5. Magnesian slate of Graylock	III.	Hudson slate.
	5. Granular quartz	I.	Cambrian.
	4. Limestone	II.	Lower Silurian limestone.
	3. Magnesian slate of Taconic mountains	III.	Hudson slates.
	2. Sparry limestone	II.	Lower Silurian limestone.
	1. Taconic slate	III.	Hudson slates.

PHASE II, 1844.

5.	*a.* Black slate. Fossiliferous	I.	Cambrian.
	b. Taconic slate "		Mostly Hudson slate.
4.	Sparry limestone	II.	Lower Silurian limestone.
3.	Magnesian slates	III.	Hudson slates.
2.	Stockbridge limestone	II.	Lower Silurian limestone.
1.	Granular quartz	I.	Cambrian.

PHASE III, 1855.

I.	*Upper Taconic.*		
2.	Black slate	I.	Cambrian.
1.	Taconic slate	III.	Mostly Hudson slate.
II.	*Lower Taconic.*		
3.	Magnesian slate	III.	Hudson slate.
2.	Stockbridge limestone and Sparry limestone	II.	Lower Silurian limestone.
1.	Granular quartz	I.	Cambrian.

Use of the name Cambrian.—There is no necessity for reviewing the Silurian-Cambrian controversy. All the facts, as understood by many writers, are accessible to the student of English geologic literature. It is my opinion that the name Cambrian should be used for the system of strata characterized by the "First Fauna."

The Cambrian System was correctly established on a stratigraphic basis in 1835, and included the same relative geologic terranes as the "Taconic System," with the exception of going a little lower in the section containing the Primordial fauna. Like the Taconic, it included the Lower Silurian (Ordovician) System, a fact noted and corrected by Dr. Emmons, *for the Cambrian*, in 1842. The Cambrian section stands intact to-day, and, on faunal evidence, separates into two great divisions, the lower of which is the Cambrian System, as used by many

* Made equivalent to the lower unfossiliferous part of Sedgwick's Cambrian as known to Dr. Emmons at that time.

writers for the system of strata characterized by the "First Fauna," and the upper the Champlain of Emmons, the Lower Silurian of Murchison, or the Ordovician of some more recent authors.

Classification of North American Cambrian Rocks.

In the classification of the fossiliferous sedimentary rocks of all countries it becomes more and more evident that the great systems—Cambrian, Silurian, Devonian, etc.—must rest on the broad zoologic characters of their included faunas and not on stratigraphic breaks between the systems, and that geologists will need to recognize the fact so well stated by Lapworth, that "we have no reliable chronological scale in geology but such as is afforded by the relative magnitude of zoological change—in other words, that the geological duration and importance of any system is in strict proportion to the comparative magnitude and distinctness of its collective fauna."* In pursuance of the above principle I have separated the Cambrian System in North America from the Lower Silurian. In the magnitude of sedimentation and extent of the fauna it ranks with the other great geologic systems, and we cannot unite it with the Lower Silurian except from reasons that, if followed out, will unite all the systems from the Cambrian to the Quaternary.

In arranging the different strata composing the Cambrian System three primary divisions are distinguished by the predominence in each of a fauna that, in assemblage of genera and species, may be separated from others whenever two or more of them occur in the same stratigraphic section. This extends to the identification of the relative geologic horizon by the fauna when its vertical or geographic connection with other faunas is not preserved. The three divisions of the table have been recognized to a greater or less extent in all the sections of Cambrian strata studied in North America, and all the observed Cambrian faunas come within their limits.

The second column in the table gives local names that have been applied within certain geologic provinces, where the fauna and the sedimentation indicate a greater uniformity of conditions than existed throughout the larger areas outlined by the first three divisions. The right-hand column gives the names of local subdivisions where the conditions of sedimentation and of life were still more restricted.

The table is a correlation of the various sections described in the introduction to U. S. Geological Survey Bulletin No. 30, and hence is tentative. It is the expression of my present knowledge and opinion. All who use it in geologic work

* Geol. Mag., vol. vi, p. 3, 1879.

should refer to the data given in that Bulletin, and decide individually upon the value of the correlations made in the table.

	Lower Calciferous.	Lower portion of the Calciferous formation of New York and Canada. Lower Magnesian of Wisconsin, Missouri, etc.
UPPER CAMBRIAN.	Potsdam. Knox. Tonto.	Potsdam of New York, Canada, Wisconsin, Texas, Wyoming, Montana and Nevada; Tonto of Arizona; Knox Shales of Tennessee, Georgia and Alabama. The Alabama section may extend down into the Middle Cambrian.
MIDDLE CAMBRIAN.	Georgia. L'Anse au Loup. Prospect.	Georgia and "Granular Quartz" formations of Vermont, Canada, New York and Massachusetts. Limestones of L'Anse au Loup, Labrador. Lower part of Cambrian section of Eureka and Highland Range, Nevada. Upper portion of Big Cottonwood Cañon Cambrian section, Utah.
LOWER CAMBRIAN.	St. John. Braintree. Newfoundland. Uinta?	Paradoxides beds of Braintree, Mass., St. John, New Brunswick, St. John's area of Newfoundland; Lower portion of Big Cottonwood Cañon Cambrian section, Utah. Uinta? (The Ocoee conglomerate and slates of East Tennessee are doubtfully included.)

DESCRIPTION OF THE MAP AND SECTION.

The map shows the geographic distribution of the strata referred to the "Taconic System" in eastern New York and western Vermont, Massachusetts and Connecticut. The data for it are taken from the Geological map of Vermont and New Hampshire, by Professor C. H. Hitchcock, 1877 (Geol. Northern New England); the maps published by Professor Dana, on the geology of the region studied by him in western Massachusetts and Connecticut, and eastern New York; and the map of southwestern Vermont, published by Professor Dana on the result of Rev. A. Wing's field studies (Am. Jour. Sci., 3d ser., vol. xiii, 1877); and for Washington and Rensselaer Counties, N. Y., as mapped from field work done by myself in 1886–87.

The line of contact of the Cambrian and pre-Cambrian rocks on the east, in Vermont, is tentative, as it is known to be incorrect in details; the data for correcting it have not been obtained.

Certain changes in the identification of the strata, as compared with the older maps, have been rendered necessary by the correlations made in this paper; and the shales, in the vicinity of the limestones south of the Rensselaer county line, have not been colored, as it is yet undetermined whether they belong to the Hudson or Cambrian Terrane. The shales immediately beneath the limestone (3) are shown as a distinct

terrane (2) in the section but on the map they are merged with the Georgia terrane (5).

The exact localities of fossils within the typical Taconic area are shown by the letter F. Many localities to the north and south are not indicated.

Section.—The geologic section crosses the Taconic area on the line marked A, B, on the map, which is very near the line of the original section published by Dr. Emmons in 1847 (Geol. N. Y., pt. 1, pl. xviii, Sec. 1). On the line C, D fossils have been found more abundantly on the eastern side, and the structure is found as in Dr. Emmons's section of 1856.

1. Cambrian quartzite—Terrane No. 1.
2. Hydromica (Potsdam ?) shales—Terrane No. 2.
3. Trenton, Chazy and other limestones of the Lower Silurian —Terrane No. 3.
4. Hudson (hydromica) shales of the Taconic range and, in the Hudson valley, the Hudson terrane—Terrane No. 4.

4*a*. A belt of strata of the Hudson terrane, faulted in between Cambrian rocks—Terrane No. 6 of text.

5, 5*a*. Slates, with interbedded limestones and sandstones of the Georgia Terrane, of the Cambrian—Terrane No. 5.

6. Pre-Cambrian (Agnotozoic) or Archean rocks. *a*, *b*, *c*, *d*, fault lines, known to the writer, in Washington County, N. Y. The hade of the Ball Mountain fault (*a*) is approximately correct (see fig. 12) while that of the other faults is probably much more oblique or inclined to horizontal than as represented. They are drawn to show where they occur and not to indicate the hade or angle of the faults. The minor undulations, faults and displacements that occur on the east side, between 3 and the gneiss are not represented.

Comparing this with Dr. Emmons's sections, we find a difference in the arrangement of the strata in the eastern half. The "Lower Taconic" embraced the strata from Terrane No. 1, on the east, to Terrane No. 3, on the west side of the Taconic range, and included *all* the strata of the original "Taconic System" as known and defined by Dr. Emmons in 1842. The "Upper Taconic" included the strata of terranes Nos. 2, 4, 4*a*, 5, and 5*a*, west of the Taconic Range, which was added to the original "Taconic System" in 1844.

I have not attempted to show that the quartzite contains interbedded limestones and schists in some localities, nor that the limestone series (3) is broken by interbedded schists or arenaceous beds; nor that, as at Graylock, the quartzite (1) extends completely beneath the synclinal of the limestone (3) and appears on the western side. It is only the illustration of the

general relations of the quartzite, limestone and schists to each other that is attempted.

To the west of the Taconic Range the section passes down through the limestone (3) to the hydromica schists (2), and thence to the great development of slates and shales with their interbedded sparry limestones, calciferous and arenaceous strata, all of which contain more or less of the Olenellus or Middle Cambrian fauna.*

No. 2 occupies the stratigraphic position of the Potsdam formation elsewhere; and 5 and 5*a* by contained fauna and stratigraphic relations, are correlated with the Granular Quartz series (1) and referred to the horizon of the Middle Cambrian, as the latter is defined in Bulletin 30, U. S. Geological Survey, and in the table of classification (*ante*).

Between the limestone (3) and the slates (5) there are several displacements, but none to displace the strata sufficiently to bring rocks of other formations in sight, and so break the section that the general relations of 3, 2 and 5 can be interpreted by me in a different manner from that given in the section.

ART. XXXIV.—*Terminal Moraines in North Germany;* by Professor R. D. SALISBURY, of Beloit, Wisconsin.

DURING the past summer some observations have been made upon the drift formations of northern Germany which may not be without interest to the students of Quaternary Geology in America. It is the writer's expectation to continue the same line of study next season. It is due toPresident T. C. Chamberlin, who has done so much for Quaternary Geology in America, to say that the study of the drift phenomena of the above specified region was undertaken at his suggestion, and that he had forecast with surprising accuracy, the results which observation has confirmed.

So far as the work has been prosecuted, attention has been mainly directed to a terminal moraine, or, more exactly, to a terminal morainic belt, which crosses Germany, and which has been traced in more or less detail from Denmark to the Russian border. In the tracing of this belt, the main reliance has been upon topography, which here, as in America, affords the most reliable and the most available single criterion for the determination of the formation.

So striking is the topography throughout the greater part of the course of the moraine in Germany, that it could not fail to

* Thirty-five species in Washington County, N. Y., as known to date. (See this Journal for September, 1887).

attract the attention of one familiar with the surface expression of terminal moraines. The determination of the general course of this belt is, therefore, attended with no difficulty, and its surface deportment, taken together with other characteristic accompaniments, is such as to leave no possible doubt as to the genuineness of its morainic character. The other features of terminal moraines upon which, in the absence of decisive topography, reliance must be placed, are never wanting where the topography is strongly marked. This is as true of the formation in Germany as in America, but the necessity of resorting to these less decisive characteristics as a prime means of determination, is here less frequent.

In some portions of its course, the morainic belt is single and strongly developed, and its limits sharply defined. In others it is composed of more or less distinct members, sometimes weak and unobtrusive, and often assuming complex relationships. The number of these constituent belts, as they now appear is not constant. In certain meridians, four have been recognized, more or less distinctly separated from each other, while in other parts, through the union of two or more of these members, the number is reduced to three, two or even one.

No attempt will be made at this time to indicate the position of these individual belts, though through considerable portions of the course of the moraines, this might be done. Detailed study will make it possible to map these constituent belts, and to determine with some degree of precision, their relationships in time.

It is to be borne in mind, therefore, that although the belt is here outlined in its entirety, and as if it were a unit, it is not to be regarded as a single moraine, or even as a belt of moraines necessarily closely connected in origin, or *in point of time*. The belt, as here outlined, embraces a broad tract, within which morainic developments are a general—a dominant fact. Occasionally the belt is seriously interrupted, in some or all its parts by broad gaps, some of which represent the drainage avenues of the ice-period, and some of which appear to be the beds of lakes which occupied reëntrant areas within the margin of the ice itself. In a general statement of the course of the moraine, and only a general statement is here admissible, these details cannot find place. Within the belt too as here outlined, there are numerous inter-morainic tracts, which are now and then of considerable proportions.

The width of the morainic belt is so great that the position of the outer and inner borders will be separately indicated. Leaving out of consideration for the moment certain subordinate, but very significant phenomena which will be adverted to

later, the course of the moraine-belt, commencing at the west, is essentially as follows:

Through the northern part of the province of Schleswig, it lies near the eastern coast of the peninsula, having a nearly north-and-south course. It passes through Flensburg at the head of Flensburg Fjord, and beyond this point assumes a course bearing slightly more to the east, but still nearly corresponding to the coast-line. Its outermost (southwestern) border lies a little southwest of the city of Schleswig, and a few miles north of Rendsburg (province Holstein), on the Eider. Continuing in the same general direction, the outer border lies a few miles north of a line connecting Rendsburg with Neu Münster. Its limit is here sharply defined, and easily recognized. Beyond Neu Münster it bears more to the south, and passes near Segeberg, Oldesloe and Mölln. Here it curves more to the eastward, and passes near Zarrentin, on Schall lake and near Boddin.

Eastward from this point (lat. 53° 35′, lon. 28° 45′), the belt is, for some distance, very complex and discontinuous, at least in its outer portions. The individual moraines are widely separated, and the area here outlined is therefore proportionally wide, and embraces much territory which is not morainic. The general course of the belt however is continuous in a direction south of east. Its southern border lies south of Pritzwalk and Wittstock (province Brandenburg), in the vicinity of Neu Ruppin, and a little north of Eberswalde (lat. 52° 45′, lon. 31° 30′). In the longitude of Pritzwalk and Wittstock, the main developments are much farther north, although reasonably strong moraines lie as here indicated. East of this point the moraines reach their southernmost extension. For some distance east of Eberswalde their course is easterly and then bears to the northward. The main developments lie north of a line passing near Soldin, Friedeberg, Woldenberg, south of Neu Stettin, and north of Konitz, from which point the outer border follows a generally northeasterly course to the longitude of Danzig.

The northern border of the moraine-belt to this point, commencing with Schleswig, follows approximately the coast line as far as Rostock. Its width is therefore very great. East of Rostock, the northern border lies north of Teterow, near Neu Brandenburg, a little south of Pasewalk and north of Stettin. Eastward from Stettin, its course is more or less direct to a point a few miles north of Danzig.

From the meridian of Danzig a moraine of huge proportions swings to the southeast, thus exhibiting on German soil, the phenomenon of morainic looping so abundantly represented in the United States. The southern border of this

eastern loop lies south of Stargard, near Jablonowo and Mantowo (lat. 53° 20′, lon. 37° 20′). Here its course becomes more easterly, and finally north of east, passing near Ortelsburg (lat. 53° 30′, lon. 38° 30′), and thence extending in a generally direct course to Lyck, near the Russian frontier (lat. 53° 45′, lon. 40°). The corresponding northern border lies north of Riesenberg (province Ost Preussen), a little north of Morungen, near Bischoffstein and Rastenburg (lat. 54°, lon. 39°).

In cases in which the individual members of the morainic series are not united with each other, they are sometimes distinctly traceable individually, and sometimes so connected by cross ranges, as to form a sort of morainic complex or network. The separate ranges are individually strong at certain places and weak at others. They are sometimes all strong on a given meridian, sometimes all weak, and again some are massive while others are feeble. The moraines or the morainic belt, therefore, considered as a unit, constitutes a very different topographic feature in different regions, and is generally much more conspicuous when the moraines are united, than when they are separated.

Apart from the relief produced by the formation itself, the country traversed by the moraine is generally level. It is therefore often a conspicuous feature, rising 200 feet or 300 feet, and even 400 feet above the surrounding country. With a given elevation it is conspicuous or unobtrusive, according as its rise from the bordering lowlands is prompt or gradual. It is sometimes so prominent as to have received the local appellation of mountain range, and numerous points are, in this level country, designated mountains. It is possible that in such cases the total elevation is not always entirely due to drift accumulation, although no evidence to the contrary is at hand. Throughout most of its course, the belt constitutes so prominent a relief feature as to have been a potent factor in determining drainage.

The topography of the moraine distinguished from the moraine as a topographic feature—is exceedingly varied. For the most part it is characterized by the knob and basin topography which is so generally characteristic of terminal moraines in similar situations. This topography finds expressions in all degrees of strength. Even when of the sag and swell, or knob and basin type, there may be, with a given altitudinal variation, wide variations of topography limited on the one hand by the nature of the material, which limits the maximum gradient of slopes, and on the other by the width of the moraine, which fixes the minor limit possible within the same. These extremes, as well as all gradations between them, find place in the moraine in question. The topography is now

rough, now gentle, according as the elevations and depressions have steep or gentle slopes. Throughout wide stretches of the moraine, the altitudinal variations, within narrow areal limits are fully 100 feet. Not infrequently, isolated basins, "kettles," no more than 10 or 12 rods in diameter, have a depth of 50 feet below the lowest points of their borders, while pointed knolls rise 100 feet or more in their immediate vicinity. Commonly the topography is less strongly marked, the undulations assuming gentler, flowing contours, with variations much less than those indicated.

More broadly considered, the relief of the moraine is not confined to so narrow limits. At many points there are variations of 200 feet or 250 feet within the moraine. These however are not commonly so closely associated as are those of smaller proportions, so that even with the greater range, the surface may appear less rough. Occasionally the moraine surface is wanting in knolls and basins, but this is rarely the case for any considerable distance.

The topography and the complexity of the moraine, together with its great width, afford abundant opportunity for the formation of lakes, which are accordingly an almost constant concomitant of the moraine. Their number is exceedingly great. So characteristic are they, and so nearly restricted to the moraine, that a tracing of the lake belt would be almost identical with a tracing of the moraine itself.

In constitution, the moraine presents all the diversities common to such formations. Sand, gravel and clay predominate each in turn, and the ratio between coarse and fine material is an ever-varying one. In general, it may be said that the moraine is predominantly sandy, at least superficially, and that the proportion of stony material is great.

Scarcely less characteristic than the features of the moraine itself, are certain deposits of drift, widely associated with it. Among these are the extensive plains of sand and gravel, particularly the former, which skirt the outer face of the moraine. In scores of localities which have fallen under notice, approach to the moraine from the south is over a wide belt of sand, which has a distinct though gradual upward incline toward the moraine. The material of these border plains becomes coarser as the moraine is neared, and contains bowlderets and even bowlders in the immediate vicinity of the range.

It is to be observed that the moraine lies far north of the southern limit of drift, just as the main moraines of America lie, throughout the larger part of their course, far north of the southern drift limit.

In all these characteristics, viz: in its composition from several members, in its variety of development, in its topographic

relations, in its topography, in its constitution, in its associated deposits, and in its wide separation from the outermost drift limit, this morainic belt corresponds to the extensive morainic belt of America which extends from Dakota to the Atlantic Ocean. That the one formation corresponds to the other does not admit of doubt. In all essential characteristics they are identical in character. What may be their relations in time remains to be determined.

It is not improbable that the outer and inner members of this series, where widely separated geographically, are also somewhat widely separated in time. The former frequently show unmistakable signs of greater age. Where the geographical separation does not obtain, this difference is also wanting. This relationship would be easily explained by supposing that, where the range is single, the margin of the ice was as far advanced at the time of the formation of the subsequent moraines (or at least at the time of the last), as at the time of the formation of the first, and that, where the moraine is two-fold or more, the ice failed at a corresponding number of moraine-forming periods, to reach its earlier position. Analogous relationships were long since recognized in America.

It may be fitting to mention a few localities where the moraine may be seen in strongly typical development. Such are (1) in province Holstein, the region about (especially north of) Eutin; (2) province Mecklenburg north of Crivitz and between Butow and Kröpelin; (3) province Brandenburg, south of Reckatel, between Strassen and Bärenbusch, south of Fürstenberg and north of Eberswalde, and between Pyritz and Soldin; (4) province Posen, east of Locknitz, and at numerous points to the south, and especially about Falkenburg, and between Lompelburg and Bärwalde. This is one of the best localities; (5) province West Preussen, east of Bütow; (6) province Ost Preussen, between Horn and Windikin.

The drift-covered area south of the indicated belt is not altogether without moraines, and in this respect also the German and American fields are similar. Furthermore, in Germany as in America, these outer developments are less continuous, partly because of subsequent erosion and partly because of their originally weaker and more discontinuous character. Detailed work will doubtless make it possible to show the connections of these local (as they now appear) fragments, some of which have but a limited development, while others may be traced for considerable distances.

Without mentioning more isolated occurrences of this kind, reference may be made to certain morainic phenomena south of Berlin, and which, though not consecutively traced, appear to constitute for some distance a traceable, though quite unob-

trusive belt. At several points both east and west there are fragments of moraines of undoubted character. These outer occurrences are significant, but their full meaning will only be understood when detailed work shall have shown their relationships. It is not impossible that a chain of such isolated formations may be found to be so situated with reference to each other, as to indicate an outer moraine of greater age than the northern group. It is possible that some of the accumulations there included, belong rather with these outer fragments, in time of origin, though not widely separated geographically from the later formations to the north. In this case, the variation in the position of the ice-front at different epochs must have been great.

The failure to bring the drift formations of the continent of Europe into closer correspondence with those of our own country, is to be attributed, in part at least, to the absence of a common basis of study. The terminal moraines are unquestionably the most conspicuous, and by means of their topography the most easily recognized of the drift formations. They are therefore especially adapted to serve as common centers of study, and with this one common phase of the drift formations, which may be in some sense a standard of comparison the work of geologists on opposite sides of the water may, more readily than heretofore be correlated, and such correlation cannot fail to facilitate the solution of the many yet unsolved problems in glacial geology.

Heidelberg, Nov. 15, 1887.

ART. XXXV.—*Note on the Viscosity of Gases at High Temperatures and on the Pyrometric use of the principle of Viscosity;* by CARL BARUS.*

BY passing gases under known conditions through capillary tubes of platinum, kept at measured temperatures between 5° and 1400°, I have found a series of data for the relation be-

* The forthcoming Bulletin of the U. S. Geological Survey to which the present note refers, is a first contribution to a research on the physical constants of rocks, the experiments of which are to follow a general plan devised by Mr. Clarence King. The Bulletin in question is restricted to methods of high temperature measurement and will be in six parts, of which the first is a brief historical introduction. Chapter I of the work discusses experiments which Dr. William Hallock and I made in New Haven with a very large high temperature apparatus. In Chapter II (which with the following chapters is my contribution) I investigate apparatus and methods for the practical calibration of electrical pyrometers by aid of fixed thermal data. In Chapter III I discuss certain pyrometric qualities of the alloys of platinum generically, and the data lead to curious electrical results. In Chapter IV I describe methods for the calibration of electrical pyrometers

tween viscosity and temperature of which the following little table is a good exhibit. Air and hydrogen are the gases chosen. In the table θ'', η'', ζ'', respectively denote the temperature, the viscosity and the coëfficient of external slip of the gas, R'' the radius of the capillary tube at θ''; and η, ζ, R, have the corresponding signification at 0° C. The measurements were made absolutely. The time of efflux (t) for a known volume of gas $V_0=50^{cc}$ nearly, varied in round numbers from $t=160^{sec}$ at 0° C. to $t=2350^{sec}$ at 1200° for air, and from $t=85^{sec}$ at 0° C. to $t=900^{sec}$ at $\theta''=1000°$ for hydrogen. R in these experiments is about $0{\cdot}0079^{cm}$. The capillary platinum tubes were used in fascicles of two, side by side, and wound together in form of a nearly compact helix, at the internal and external surfaces of which temperature was measured. From the absolute values of $\eta'' : \left(1+4\frac{\zeta''}{R''}\right)$, the quotients in the third column of the table are computed, which quotients in proportion as ζ'' approaches zero reduce to $\eta'' : \eta$. With this value I have compared $(1+\alpha\theta'')^{\frac{2}{3}}$ where $\alpha=0{\cdot}003665$. This compari-

	θ''	$\dfrac{\eta''}{\frac{1+4\zeta''/R''}{\eta}{1+4\zeta/R}}$	$\sqrt[3]{(1+a\theta'')^2}$	Diff.
Air (Table XXV)	565°	2·083	2·113	−·030
	592	2·117	2·158	−·041
	995	2·693	2·785	−·092
	1216	3·147	3·099	+·048
Air (Table XXVIII)	442	1·991	1·900	+·091
	569	2.149	2·119	+·030
	982	2·711	2·766	−·055
	1210	3·214	3·092	+·122
Hydrogen (Table XXVI)	961	2·772	2·734	+·038
	1212	3·581	3·095	+·486*
Hydrogen (Table XXVII)	418	1·935	1·858	+·077
	512	2·098	2·023	+·075
	520	2·113	2·036	+·077
	952	2·760	2·721	+·039

* Platinum pervious to hydrogen.

(notably the thermo-element) by direct comparison with the air-thermometer. I have given the porcelain bulb a *re-entrant* form, the bottom folding inward in such a way as to form a narrow cylindrical tube, the closed end of which is at the center of figure of the bulb. Into this central tube the junction of the thermo-couple to be calibrated is inserted. To further insure identity in the environments of the two pyrometers to be compared, the air thermometer bulb is snugly surrounded by a spherical muffle revolving around a horizontal axis. This muffle is in its turn surrounded by the walls of a nearly spherical furnace, the burners of which are set something like a force-couple and blow into the furnace a cyclone of flame revolving around the vertical. Chapter V concludes with a full experimental discussion of the subject set forth in the above text.

son is made in the fourth column and the residual errors inserted in the final column. The data given are typical values. ζ symbolizes Helmholtz's "Gleitungs-coefficient."

From the table it follows that for the range of temperatures within which I have observed the *mean* increase of gaseous viscosity takes place proportionally to the two-thirds power of absolute temperature. Interpreted by aid of the well-known Clausius-Maxwell relations, the results of the table may be stated succinctly thus: The mean free path of the molecule of a perfect gas varies directly as the sixth root of its absolute temperature. I had hoped to find that at temperatures sufficiently high the mean free path would be independent of temperature, a law to be regarded as a criterion of a perfect gas and for which the experiments of E. Wiedemann when used to interpret the low-temperature results of O. E. Meyer, Puluj, Warburg, Obermayer, and particularly the admirable researches of Holman* seemed to contain suggestive evidence. But after applying many devices for the removal of errors, I found that my original results were not essentially changed. Accepting the law of sixth roots as indicating perfect gaseity (i. e. the non-occurrence of ephemeral mechanically cohering molecular aggregates) it appears that the *linear* magnitude, mean free path, is proportional to the cube root of the velocity of the mean square,—a singularly suggestive result.

The chief discrepancy of my work is this, that the temperature measured externally is not identical with the temperature at which transpiration actually occurs. Taking the transpiration data alone they show a surprising degree of accordance even above 1300°. If $[\theta'']$ be the temperature computed from transpiration data under assumption of the above law, I found in successive measurements, for instance:

θ''	$[\theta'']$	θ''	$[\theta'']$	θ''	$[\theta'']$	θ''	$[\theta'']$
436°	450°	568°	575°	975°	971°	1210°	1245°
446	459	570	577	981	972	1210	1247
455	469	575	581	990	982	1209	1245

If the law governing the thermal variations of the viscosity of a gas were rigorously known, Poiseuille-Meyer's equation applied to transpiration data would enable us to measure tem-

* After a careful consideration of his own results and those of all earlier observers, Mr. Holman has discarded exponential relations altogether. For my own part, I believe that at the present stage of research a conservative policy is the wiser. In chemistry the hypothesis of residual affinity is fast gaining ground. Hence before final decision can be made, it will be necessary to have exhausted data for an interval of temperature (say 500° to 1000°) within which the ephemeral molecular aggregates in question may reasonably be assumed to be absent. Discussion must be reserved for the Bulletin.

perature absolutely, over a wider thermal range and with a degree of precision and convenience unapproached by any other known method.

The present method lends itself easily for the study of dissociation phenomena in gases. I hope to be able to show that in the case of imbedded capillaries, the method may be used for the high temperature study of vapor tensions and phenomena near the critical temperature. From such points of view I am justified in believing that the favorable character of my experiments introduces a new instrument of pyro chemic research; an instrument which in addition to the special work to which it may be applied, always subserves the purpose of a pyrometer, and which is particularly available for the coördination of values within a field of high temperature where absolute data are either isolated or wanting.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Boiling-point and molecular formula of Stannous chloride.*—Biltz and Victor Meyer have determined the boiling point of stannous chloride, the temperatures being estimated by the air thermometer. The first series of experiments gave the value 604·5°, the second series 607·7°; the mean being 606·1°. Since this substance is easily procured and is non-volatile, it may serve a useful purpose for vapor density determinations, for which we now have sulphur, boiling at 448° and phosphorus sulphide boiling at 518°. Experiments on the vapor density of stannous chloride show that this constant lessens very slowly with rise of temperature. But they do not confirm the formula Sn_2Cl_4, originally given by V. and C. Meyer. The results obtained are considerably greater than the formula $SnCl_2$ requires, but the authors have not obtained a constant value corresponding to the doubled formula. The details of the method will be given shortly.—*Ber. Berl. Chem. Ges.*, xxi, 22, Jan. 1888. G. F. B.

2. *On the occurrence of Germanium in Euxenite.*—Krüss has discovered the existence of germanium in the acid oxides obtained from euxenite. The mixed oxides were boiled with hydrogen chloride to extract the iron, washed and digested for eight days with ammonium sulphide in a closed vessel. Though all sulphides soluble in ammonium sulphide must have been thus taken up, analysis showed no arsenic, antimony, tin, molybdenum, tungsten, etc. in the solution; and yet on evaporation and ignition, the solution left a fixed white residue, soluble in ammonium sulphide. The white sulphide obtained by Winkler's method mixed with sulphur, was heated in a current of carbon dioxide and left a

crystalline mass of dark red sulphide showing a metallic luster. In a current of hydrogen, the sulphide yielded pure germanium having all the properties of the metal obtained from argyrodite. The amount present in euxenite is about one-tenth of one per cent. —*Ber. Berl. Chem. Ges.*, xxi, 131, Jan., 1888. G. F. B.

3. *On the Double Acetate of calcium and copper.*—RÜDORFF has prepared and analyzed anew the large quadratic crystals described first by Brewster. They were prepared by dissolving 25 grams copper acetate and 66 grams calcium acetate in 350 c.c. of water, moderately heated. On cooling the crystals separated. Upon analysis they gave the formula $CaCu(C_2H_2O_2)_4 . (H_2O)_4$; and not $(H_2O)_8$ as determined by Ettling.—*Ber. Berl. Chem. Ges.*, xxi, 279, Feb. 1888. G. F. B.

4. *Ueber die Reaktionsgeschwindigkeit zwischen islandischem Doppelspat und einigen Säuren.*—A recent number of that excellent new journal, the *Zeitschrift für physkalische Chemie* (vol. ii, p. 13), contains an interesting article by W. SPRING on the rapidity with which Iceland Spar is attacked by certain acids, in continuation of an earlier article in which marble was the substance investigated. The surfaces exposed to the acid were the cleavage planes, and also planes cut parallel and perpendicular to the vertical axis. At a temperature of 15° it was found that the surfaces parallel to the axis dissolved with sensibly the same velocity as the cleavage planes, but this equality disappeared as the temperature rose and at 35° and 55° the reaction was 1·23, 1·28 times more rapid. In the case of the surfaces normal to the axis at 15° the rapidity of solution was greater but did not increase so rapidly with increase of temperature. In taking the ratio of the velocity of solution for the vertical and transverse surfaces at the different temperatures the number 1·14 is obtained as the mean, which, it is interesting to note, is not far from the relation of the two refractive indices to each other (viz: 1·115). In other words the author establishes a relation between chemical activity and optical elasticity.

5. *The Integral Weight of Water;* T. STERRY HUNT.—In a paper on Chemical Integration published in this Journal for August, 1887, and reprinted in the *Chemical News*, Sept. 23d and 30th, it was said that in comparing the densities of liquid and solid bodies with those of known gaseous species, such as water-vapor and carbon dioxyd, "or in the last analysis with the density of the hydrogen unit, . . . we get the specific gravity of these bodies, the dyad integer of hydrogen at 0° and 760^{mm} (H_2=2·0) being unity." Subsequently, in a paper on Integral Weights in Chemistry, in the *L., E. and D. Philosophical Magazine* for October, 1887, it was stated that a litre of hydrogen gas "at 0° and 760^{mm} being assumed as the unit of volume for all species, the weight of a litre of any other vapor or gas *at the standard temperature and pressure is its integral weight.* In like manner, the integral weight of a liquid species is the weight of the same volume at its boiling point under a pressure of 760^{mm}. . . . The

weights thus obtained for equal volumes of the various liquid and solid species are evidently the specific gravities of these species; that of hydrogen at the standard temperature and pressure being unity ($H_2=2{\cdot}0$). They are at the same time the integral weights of the species compared." Notwithstanding this clear statement in both papers that it is hydrogen at 0° and 760^{mm} which is to serve as the unit of specific gravity alike for gaseous, liquid and solid species, the reader will find in these papers, and also in the first edition of the author's *New Basis for Chemistry* (1887), an error in the subsequent calculation. The problem having been approached from the comparison of the weights of equal volumes of liquid water at 0° and 100°, and of water-vapor at 100° and 760^{mm}, by an inadvertence (until now unperceived) the weights alike of hydrogen gas and of water-vapor at the latter temperature were substituted for their weights at 0° and 760^{mm}; thus leading to a grave error in the figure given for the integral weight of liquid water, and of bodies for which it serves as the unit of specific gravity, and making it equal 29244. In fact, however, taking as the unit of weight that of the litre of hydrogen gas at standard temperature and pressure (0° and 760^{mm}) and comparing it with that of liquid water at 100° (its temperature of formation at 760^{mm}), when a litre of it weighs 958·78 grams, we have:

$$0{\cdot}0896 : 958{\cdot}78 :: 2 : x = 21400{\cdot}3.$$

This value is thus alike the specific gravity of the liquid on the hydrogen basis and its integral weight, which, if we take $H_2O=17{\cdot}96$, corresponds very closely to $1192(H_2O)=21408$; ice being probably $1094(H_2O)$, calcite, $584(CCaO_3)$ and aragonite, $630(CCaO_3)$. While the writer regrets this error in calculation, made in direct contradiction to the principles laid down by him in both of the papers cited, it will be seen that its correction in no way affects their argument, which he hopes to develop further at an early day.

Washington, D. C., February 22, 1888.

6. *Absorption Spectra.*—The relation of absorption spectra to the various physical constants of the substances which afford the spectra has not been fully made out. Fr. Stenger's experiments conduct him to the conclusion that the absorption of light by various substances depends primarily upon the size of the physical molecule. Changes in the state of aggregation, or changes produced by different media in which a substance is dissolved produce absorption spectra of different character only when the state of the physical molecule is also altered. The author discusses, from this point of view, the law of Kundt connecting the index of refraction and the dispersive power of a medium in which a substance is dissolved with the displacement of absorption bands toward the red end of the spectrum. Vogel's researches upon the absorption of dyes in the solid state, obtained by staining gelatine films, and their absorption in the liquid state is also adduced as an evidence of the truth of the author's

hypothesis that the physical molecule in concentrated solutions is more complicated than in diluted solutions.—*Ann. der Physik und Chemie*, No. 4, 1888, p. 577. J. T.

7. *Wave-length of the two red lines of potassium.*—A determination by M. H. Deslandres gives for the stronger line 766·30, for the weaker 769·63. As a measure of comparison the wave-length of D_2 was taken as 588·89.—*Compte Rendus*, March 12, 1888. J. T.

8. *Explosion of gases.*—A. von Œttingen and A. von Gernet have repeated the work of Bunsen, Berthelot and Vieille, and also that of Mallard and Le Chatelier upon this subject making use however of instantaneous photography to study the phenomena. A rotating mirror was employed with a metallic pointer to which an electrical spark passed when the mirror was in the right position to reflect an image of the eudiometer tube, in which the explosion took place, into a photographic camera. The same spark served to explode the gases. The most sensitive Beernaert plate gave no trace of an image. No results could be obtained by staining the plates with cyanine or with azaline. Eastman's negative film paper, however, gave a faint image. The authors were compelled to sprinkle certain powders in the eudiometer tube. Chloride of copper gave the best results. Plates of the phases of the explosions accompany the paper. The experiments show that the explosion of hydrogen is not accompanied by light. The resulting high temperature, however, produces a disintegration of the glass of the eudiometer tube and produces a certain illumination. Three species of wave motion are observed: first, a fundamental wave, which is entitled Berthelot's wave; second, more or less parallel secondary waves; third, polygonal waves of smaller amplitude. The photographic image of the electric spark which was received upon the same plate as that of the explosion, enabled the authors to estimate the velocity of the explosion. The result obtained, 2800 meters per second, is of the same order of magnitude as that obtained by Berthelot. The authors agree, in the main, with Berthelot's conclusions, differing only in reference to the beginning and the end of the explosion. They explain the secondary waves on Bunsen's hypothesis of the reflex action of waves due to successive explosions produced by the electrical spark. They, therefore, term these Bunsen's waves.—*Ann. der Physik und Chemie*, No. 4, 1888, pp. 586–609. J. T.

9. *Dust particles in the Atmosphere.*—John Aitkin in an article read to the Royal Society of Edinburgh, gives a method of estimating the number of these particles in the air. The method is based upon the hypothesis that in a receiver filled with super-saturated air when there are few dust particles present the fog particles are large and are seen to fall like rain inside the receiver. A small glass receiver was connected with an air pump and with a cotton wool filter. Inside the receiver was placed a small stage with a silvered mirror ruled with fine lines which

served to enumerate the fine drops. The latter, under a microscope, appear brilliant, upon a dark suface. The following are some of the results obtained by this method :

Source of the air.	Number per c. c.
Outside air, raining	32,000
Outside air, fair	130,000
Room	1,860,000
Room, near ceiling	5,420,000
Bunsen Flame	30,000,000

—*Nature*, March 1, 1888, p. 428. J. T.

10. *Magnesium and Zinc.*—Hirn has investigated the electropositive character of magnesium with the view of replacing zinc in certain batteries. In the Daniell cell its E. M. F. is 2 volts; in a Grove 2·9 volts; in a Leclanché, 2·2 volts, and in a bichromate-cell, it gives as much as 3 volts. The local action, however, is considerable and its constancy uncertain.—*Nature*, March 22, 1888, p. 497. J. T.

11. *Gravity.*—In a discussion upon gravitation at a meeting of the Physical Society of Berlin, Helmholtz explained his conception of the action of gravitation. He considers gravitation as being the law of nature, established by experience, that every body, when, in the neighborhood of another body is subject to an acceleration which is proportional to its mass and diminishes in the ratio of the inverse square of the distance between them. Such a law of nature as this, established as it is on the basis of experience, is on the whole not unsatisfactory.—*Nature*, March 8, 1888, p. 455. J. T.

II. Geology and Mineralogy.

1. *Geology: Chemical, Physical and Stratigraphical;* by Joseph Prestwich. In two vols. Vol. II, pp. 606. 8vo, *Stratigraphical and Physical.* Oxford, 1888. (Clarendon Press.)—The first volume of Prof. Prestwich's valuable work was issued in 1886. This second volume commences with the oldest formations, and closes with the Quaternary. Its first chapter gives a very convenient table of the geological series of England with their equivalents in the different countries of Europe, and follows this with a corresponding table of the rocks of India, with an enumeration of their prominent genera of fossils; and the same for North America, Australia, New Zealand and South Africa. The author makes the Cambrian end with the Tremadoc slates, and divides the Silurian (or the remainder of it) into Upper and Lower. The volume is full in its accounts of the several formations and their distribution in Great Britain and other countries, and in illustrating figures; and its plates of fossils are particularly fine. A handsome folded plate represents "the probable extent of land covered by ice and snow during the Glacial period, their extent now and the present boundaries of floating ice," and its importance is doubled by being also a good bathymetric map of the oceans from recent data. An excellent colored geological

map of Europe and Great Britain, folded and on cloth, makes a frontispiece to the volume and gives great value to the work. The map is by Wm. Topley, F.G.S., and J. G. Goodchild, F.G.S. It is the only map of the kind in any treatise on geology in the English language.

2. *On the level-of-no-strain and mountain making.*—The memoir by Mr. Davison and Prof. Darwin on the contraction-theory of mountain-making was noticed in the last number of this Journal. The same subject has been further discussed by the Rev. O. Fisher and Mr. T. Mellard Reade (Phil. Mag. for January and March.) All of these authors agree in the existence of the level-of-no-strain in the earth, first announced by Mr. Reade, and their estimates of its depth do not vary very widely, all agreeing that it must be within a few miles (2 to 5) of the surface. As regards the amount of crumpling of strata on this basis Mr. Darwin (as noted before) makes it small and yet not entirely insignificant (228,000 sq. miles in 10 million years). Mr. Fisher's conclusions upon the supposition of a temperature of solidification of respectively 7000° and 4000° are contained in the following table:

Temperature of solidification.	7000°	4000°
Depth of level of greatest cooling	54 miles	31 miles
Depth of level of no strain	2 miles	0·7 miles
Temperature of level of no strain	358° F.	124° F.
Mean height of elevations	19 feet	2 feet
Total contraction of radius	6 miles	2 miles

Mr. Reade discusses some of the geological consequences of the level-of-no-strain and concludes that it is "plain to demonstration that the lateral pressure that forced up the mountains could not reside in a shell of compression only 5 miles thick having a zero strain in the under side."

3. *Geology of Rhode Island; Franklin Society Report.* 130 pp., 8vo., 1887. Providence, R. I.—This report is largely bibliographic, but is very full in notes that review well what is known on the geology of the State and show who have been the observers. They also make it apparent that no thorough study of the geology of the State has been undertaken. The State contains the coal formation among metamorphic rocks, and this alone makes it one of the three or four best centres to start from for the study of New England geology.

4. *Annual Report for* 1886 *of the Geological Survey of Pennsylvania.* 8vo.—This part of the Report of 1886 contains Part II, on the Oil and Gas Region, by J. F. Carll; a chapter on the Chemical composition of Natural Gas, by F. C. Phillips, and a Bibliography of Petroleum.

5. *Annuaire Géologique universel, Revue de Géologie et Paléontologie;* dirigée par Dr. L. Carez and H. Douvillé, avec le concours de nombreux Géologues Français et étrangers; publié par Le. Dr. Dagincourt. Tome III. Paris, 1887.—The former volumes of this Annual contained, besides lists and abstracts of geological papers of the year, a catalogue of geologists of different countries, with their places of residence. The present is con-

fined wholly to the former purpose, and in it 777 pages are devoted to the Geology and 235 to the Paleontology of 1886. It is a work that geologists, whatever their special department, will find very useful if not indispensable.

6. *The Geological Record for* 1879. An account of works on Geology, Mineralogy, and Palæontology published during the year with supplements for 1874–78. Edited by W. WHITAKER and W. H. DALTON. 418 pp. 8vo, London, 1887, (Taylor and Francis.)—This comprehensive volume, like its predecessors in scope, will be thoroughly welcome although it is somewhat late in appearing. For the future it is announced that the editorship has passed into the hands of Mr. Topley and the work is to be brought up to date by publishing the titles only of papers from 1880–87. The portion from 1880–1884 is finished and in great part printed, making two volumes. That for 1885–87 is in hand though not yet in type. Subscribers will be quite ready to respond to the suggestion of the editor-in-chief, that the delay should be pardoned in view of the fact that the board of workers labor without pecuniary return.

7. *A Manual of the Geology of India. Part IV: Mineralogy* (mainly non-economic), by F. R. MALLET. 179 pp. 8vo, with 4 plates. Calcutta and London, (Trübner & Co.) 1887.—The economic side of the mineralogy of India has already been discussed in Part III of this work by Mr. V. Ball. The scientific treatment of the same subject has now been taken up by Mr. F. R. Mallet, and this important contribution to mineralogical literature is the result. It is a subject about which our knowledge has been in the past vague and scanty, and although much remains to be done in the way of investigating the mineral treasures of India, this complete and accurate presentation of what is now known about them is of great value.

8. *Brief notes on recently described minerals.*—ARSENIOPLEITE.—Occurs in reddish brown cleavable masses forming small veins or nodules with rhodonite and hausmannite in a crystalline limestone from the Sjö mine, Gryhyttan, Sweden. It is shown optically (Bertrand) to be uniaxial and negative, probably rhombohedral. Analysis gave:

As_2O_5	Sb_2O_5	MnO	Fe_2O_3	PbO	CaO	MgO	H_2O	Cl
44·98	*tr.*	28·25	3·68	4·48	8·11	3·10	5·67	*tr.* = 98·27

This is corrected to give Mn_2O_3 7·80, MnO_2 21·25, H_2O 4·54, final sum 97·94. It is closely related to the large group of manganese arseniates from Sweden.—*L. J. Igelström* in *Bull. Soc. Min.*, vol. xi, 39, 1888.

BARKEVIKITE, CALCIOTHORITE, MELANOCERITE, NORDENSKIÖLDINE, ROSENBUSCHITE.—In a preliminary paper giving an outline of results obtained in a study of the augite- and elæolite-syenite veins of southern Norway, Brögger has briefly described several new species and given new facts about many others, as låvenite, gibbsite, homilite, natrolite, leucophanite, meliphanite, etc.

Barkevikite is a hornblende mineral near arfvedsonite, but distinct from that in optical characters. Calciothorite is a hydrous mineral consisting of thorium and calcium silicate and probably (like thorite, orangite, eucrasite, frejalite) an alteration product of an original thorium silicate near zircon in form and composition ($ThSiO_4$).

Melanocerite is a complex silicate of the cerium metals, yttrium and calcium, with other substances in small amount including 3·19 p. c. B_2O_3; it is found in tabular rhombohedral crystals of a dark brown color. Nordenskiöldine is a mineral having the remarkable composition $CaO . SnO_2 . B_2O_3$. It occurs in tabular crystals belonging to the rhombohedral system. Color sulphur yellow. Hardness = 5·5–6; sp. gravity = 4·20. Rosenbuschite is a silicate of calcium and sodium with zirconium, titanium and also lanthanum in small amount. It occurs in orange-gray monoclinic crystals near wollastonite and pectolite in angle, and is characterized as a zirconium-pectolite. Hardness = 5–6; sp. gravity, 3·30. — *W. C. Brögger in Geol. För. Förh.*, vol. ix, 247, 1887.

Barysil.—A new lead silicate from the Harstig mine, Pajsberg, Sweden. It occurs in iron ore with calcite, yellow garnet, tephroite and galena. Crystallization hexagonal with basal cleavage. Color white. Hardness = 3; sp. gravity, 6·11–6·55. Analysis gave:

SiO_2	PbO	MnO	FeO	CaO	MgO	ign.
16·98	77·84	3·49	0·16	0·41	0·58	0·66 = 100·12

This corresponds to $3PbO . 2SiO_2$.—*A. Sjögren and Lundström* in *Öfv. Vet.-Akad. Förh.*, xlv, 7, 1888.

Belonesite (Belonesia), Cryphiolite (Crifiolite).—Two species described by A. Scacchi in a memoir upon a fragment of an old volcanic rock enveloped in the Vesuvian lava of 1872. Belonesite occurs in minute acicular crystals referred to the tetragonal system; they are white and transparent. Qualitative tests lead to the conclusion that in composition it is a molybdate of magnesium, $MgO . MoO_3$.

Cryphiolite occurs in small tabular monoclinic crystals covered and concealed (as the name suggests) by apatite. The color is honey-yellow; sp. gravity = 2·674. An analysis gave:

P_2O_5	MgO	CaO	Loss
48·91	33·58	14·60	2·91 = 100

The presence of fluorine is suggested and the possible amount estimated as 6·93 p. c., which brings the mineral near wagnerite in composition.—*Mem. Accad. Napoli*, II, i, No. 5.

Bementite.—Occurs in stellate aggregations with foliated structure, resembling pyrophyllite. Friable. Sp. gravity, 2·981. Color pale grayish yellow. An analysis yielded:

SiO_2	MnO	FeO	ZnO	MgO	H_2O
39·00	42·12	[3·75]	2·86	3·83	8·44 = 100

This corresponds approximately to $2(H_2,Mn)O . SiO_2$; the water goes off above 200°. Occurs embedded in calcite at Franklin

Furnace, N. J. Named after Mr. C. S. Bement, of Philadelphia. —*G. A. König in Proc. Acad. Nat. Sci., Philad.*, 1887, 311.

DIHYDRO-THENARDITE.—A sodium sulphate containing two molecules of water. It forms a thin bed on the shores of Lake Gori, Tiflis, Russia, and crystallizes in the monoclinic system.—*Markownikow in Ber. Chem. Ges.*, 1887, 546 (J. Russ. phys. ch., Ges.).

FIEDLERITE, LAURIONITE.—Two related minerals found in the old lead slags of Laurion, Greece, and produced by the action of the sea-water upon them during the past 2,000 years. Laurionite occurs in white prismatic crystals (orthorhombic) not far from mendipite in angle. Hardness, =3·5. Composition, $Pb(OH)_2 . PbCl_2$; an analysis by Bodewig yielding:

Pb 79·38 O 3·17 Cl 13·77 H_2O 3·68 = 100

Fiedlerite is related in composition, but no analysis has been given. It occurs in minute tabular monoclinic crystals, in part twins.—*G. vom Rath in Sitzungsber. Nied. Ges. Bonn*, June 6, 1887; *Köchlin in Ann. Mus. Wien*, vol. 2, 185, 1887.

LAUBANITE.—A zeolite resembling stilbite from the basalt near Lauban, Silesia. Occurs in fine fibrous radiated aggregates, sometimes spherical, of a snow-white color. Hardness, 4·5–5; sp. gravity = 2·23. Analysis gave:

SiO_2 47·84, Al_2O_3 16·74, FeO 0·56, CaO 16·17, MgO 1·35, H_2O 17·08=99·76

This corresponds to $2CaSiO_3 + Al_2(SiO_3)_3 + 6H_2O$, which is not far from laumontite.—*H. Traube in Jahrb. Min.*, 1887, vol. ii, 64.

MARTINITE.—Occurs as a pseudomorph having the form of gypsum in the guano on the island Curaçoa. In white or yellowish aggregates of colorless microscopic rhombohedrons. Sp. gravity, 2·894. Analysis gave:

P_2O_5 47·67 CaO 46·78 H_2O 4·52 Organic 0·75 Insol. 0·20=99·92

The formula suggested is $2Ca_3(PO_4)_2 + 4CaHPO_4 + H_2O$.—*J. H. Kloos, Jahrb. Min.*, 1888, vol. i, 41 ref.

METALONCHIDITE.—A mineral from the St. Bernhard mine near Hausach in Baden. It is essentially a variety of marcasite, agreeing with it in form and characterized by the presence of 2·7 p. c. of arsenic with some nickel and lead, thus approximating closely to Breithaupt's lonchidite.—*Sandberger in Œst. Zeitschr. Berg-Hütt.*, xxxv, 1887.

9. *Note on Xanthitane;* by L. G. EAKINS (communicated.)—Through the kindness of Mr. Wm. Earl Hidden, Prof. Clarke has lately received some fine specimens of Xanthitane, first described by C. U. Shepard, this Journal, 1856, vol. xxii, p. 96, which were turned over to me for examination. The material is from Green river, Henderson Co., N. C., and is undoubtedly an alteration product of sphene—following the form very closely. It is light yellow, friable and mixed with impurities which cannot be removed, preventing the determination of whether or not it is a definite mineral, but it is interesting from the fact that it apparently represents a clay with the silica replaced by titanic oxide.

Specific gravity 2·941 at 24°. The air dried material loses 6·02 per cent of water at 100°. The following analysis is on material dried at 100°.

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	H_2O
1·76	61·54	17·59	4·46	0·90	*tr.*	4·17	9·92=100·34

Laboratory, U. S. Geol. Survey, Washington, D. C.

III. Botany and Zoology.

1. *Recent contributions to our knowledge of the vegetable cell.* (Second paper, continued from page 344.)—Loew and Bokorky distinguish between active and passive albumin in vegetable cells. The former is characterized by its great chemical instability, and especially by its property of reducing silver solutions even when they are very dilute: the latter, on the other hand, is relatively stable and is not readily changed or oxidized. These distinctions have been pointed out by the authors in various communications, more recently in a treatise on certain relations of protoplasm. According to them, active albumin, in combination with water, forms all living protoplasts, and, at the death of the cell, passes over into "common" or passive albumin. The authors (Bot. Zeit., Dec. 30, 1887) announce that they have detected active albumin also in cell-sap in many species of Spirogyra. From its solution in cell-sap it is precipitated whenever a dilute solution of ammonic carbonate is allowed to act on the cells. A granular precipitate appears not only in the plasma-membrane where the granules are confined within or are attached to the membrane, but in the cell-sap as well, the latter granules settling, after a time, to the lower part of the cell. *These granules do not occur in either the membrane or the cell-sap if the cell has been previously killed by pressure, cutting, or by chemical means.*

It is interesting to compare these statements with those made by Charles Darwin and others. The views of Mr. Darwin are well known by readers of his Insectivorous Plants (see page 39), and need not be further alluded to here. Pfeffer explains the appearance of aggregation in a different way: he regards the precipitate as consisting of tannate of albumin, which forms on account of the neutralization of the cell-sap by means of the ammonic carbonate. Pfeffer calls attention to the fact that the precipitate re-dissolves when an organic acid, for instance, citric, is added, and falls again when the sap becomes again alkaline. He has shown that the precipitation is effected by the addition of a tenth per cent solution of ammonic carbonate, and that re-solution occurs when a two-hundredth of one per cent solution of citric acid is employed. Loew and Bokorky state, however, that the cell-sap of Spirogyra is not acid in reaction, and that it contains no free acid. Therefore, according to them, Pfeffer's explanation of the phenomena is not satisfactory. The so-called "aggregation" is, as Francis Darwin and others have pointed out, a common occurrence in many cells. It appears to demand further investigation.

It is a familiar fact that the crystalline forms of calcium oxalate which occur in plants are referable to two crystalline types: (1) tetragonal or quadratic, when they have six equivalents of water; (2) monoclinic or clinorhombic, when they have two equivalents of water. Souchay and Lenssen attributed the difference to difference in the rate of crystallization, the first type resulting from rapid precipitation, the latter from a slower reaction. That the two types can occur in the same liquid is proved by a simple experiment suggested by Kny: on a glass slide is placed a drop of gelatin with a crystal of oxalic acid on one edge, at the opposite edge of the drop is placed a fragment of calcium chlorid. The two substances soon begin to form at their point or line of contact a white precipitate, first of octahedra, and later of a few monoclinic crystals intermingled with them. Haushofer has stated that the character of the mother liquor exerts a controlling influence on the shape of the crystals and their content of water; according to him the tetragonal crystals are formed from dilute neutral or alkaline calcium solutions at the ordinary temperature of the room. The other type is produced when there is a slight excess of oxalic acid or when the temperature is much higher. At this point Kny has undertaken a re-investigation of the subject (Ber. Deutsch. Bot. Gesellschaft, 8, 1887). He concludes that the relative concentration of the solutions in question has a great, even if not controlling, influence in determining the form of the crystals. In the course of his experiments he made some interesting observations regarding the inclusion of coloring matters in the crystalline structure. Certain aniline and other coal-tar dyes tinged some of the crystals while other dyes were without any effect. Thus in the dialyzer, crystals of the monoclinic type were tinged by eosin while the octahedra remained colorless; on the other hand, by aniline-blue both were distinctly colored. But in both cases the larger crystals remained without color. Fuchsin failed to color any of the crystals. G. L. G.

2. *Garden and Forest.* A weekly Journal of Horticulture and Arboriculture, conducted by Professor C. S. SARGENT, of Harvard University. It is pleasant to note that this periodical fully meets the expectations which were formed when the announcement of its publication was first made. Aside from matters of general and public interest, like the subjects of forest preservation, the care of plants, and the like, each number thus far has been enriched by a description of some plant of botanical (and often horticultural) interest, by Dr. Sereno Watson. These articles by Dr. Watson have been illustrated by Mr. Faxon's excellent drawings. The journal promises to be a substantial addition to the list of scientific periodicals, while, at the same time, it preserves to a large degree elements of general popularity. G. L. G.

3. BIBLIOTHECA ZOOLOGICA.—The first number* of this im-

* Bibliotheca Zoologica—Original-Abhandlungen aus dem Gesammtgebiete der Zoologie. Herausgegeben von Dr. Rud. Leuckart in Leipzig und Dr. Carl Chun in Königsberg. Heft 1, Die Pelagische Thierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächenfauna. Geschildert von Prof. Dr. Carl Chun in Königsberg. Mit 5 Tafeln.

portant zoological periodical is published. It is edited by Professors Leuckart and Chun and they propose to devote this new serial to more elaborate monographs than can from their size or the number of their illustrations easily find a place in zoological periodicals. The Bibliotheca Zoologica will hold in zoology very much the same place which Palæontographica and similar publications hold in palæontology. The first number contains a most interesting monograph on the existence of a pelagic fauna at great depth and its relation to the surface pelagic fauna. Dr. Chun was engaged upon a monograph of so-called deep-sea Siphonophoræ collected by Chierchia during the voyage of the "Vettor Pisani." Though collected on the sounding line they were labelled with the utmost precision as living below 1000 meters. Chun who was also preparing a monograph of the Mediterranean Siphonophores came to the conclusion that the collection of Chierchia supported the views of Studer that peculiar Siphonophores formed an important part of a pelagic deep-sea fauna. Under the auspices of the Zoological Station at Naples he carried on most successful deep-sea tow net experiments from August to October, 1866. Unfortunately this expedition, interesting as its results are, does little toward settling the subjects under discussion because neither the distance from shore nor the depths investigated were great enough to eliminate the disturbing effects of close proximity to land; as it was near the continental slope, on the very edge of which Dr. Chun trawled with the tow net. The results are further vitiated from the fact that they have been carried on in a closed sea where the conditions of temperature are strikingly different from those of the Atlantic, and where at a depth of about 500 fathoms we find already the lowest temperatures of the deepest part of the Mediterranean. The minimum seasonal differences of temperature between that and the surface cannot be contrasted to oceanic conditions.

Dr. Chun made use for his investigations of an ingenious self-closing tow net invented by Captain Palumbo of the "Vettor Pisani." It may be closed at any given point by means of a propellor working in a rectangular frame attached to the tow net on the same principle as the propellor for upsetting the Negretti Zambra deep-sea thermometer and the Sigsbee water bottle. The little steamer "Johannes Müller" of the Naples Zoological Station made an excursion to the Ponza Islands as well as expeditions to the Gulf of Salerno, to Ischia and Ventotene.

The contents of the deep-sea tow nets used by the Challenger could not be assigned to any definite depth as the nets were not closed either on the descent or the ascent. Neither can the method adopted on the "Blake" of collecting at intermediate depths by means of the Sigsbee collecting cylinder be considered decisive. It had not been tried long enough or frequently enough at great depths (it was not carried beyond 150 fathoms) to decide the depth to which the surface pelagic fauna might sink or to

prove the existence of an intermediate deep-sea fauna in the depths between the surface fauna and the deep-sea fauna.

From the depth of 1300 meters Dr. Chun brought up a large pelagic fauna. Small Craspedote Medusæ, Ctenophores, Dyphiæ, Tomopteridæ, Sagittæ, Alciopidæ and numberless Copepods, Stylocheiræ, larvæ of Decapods, Appendiculariæ, Pteropods and small transparent Cephalopods. Dr. Chun assumes that where he found this mass of Invertebrates there were no currents and that so rich a booty brought up by a hap-hazard cast of the net indicates a wonderful richness of the deep-sea pelagic fauna, especially when we remember that surface pelagic fishing is only successful in the wake of tide currents, calm streaks and the like. But there is nothing to show that so close in shore there is not a more or less active interchange of the fauna from the shore slopes to that of the greater depths. Should the observations of Dr. Chun be repeated off shore in the deep water of oceanic basins and the existence of this deep-sea pelagic fauna proved beyond a doubt, it will help to explain the manner in which the deep-sea fauna obtains its food; nor will it be necessary to suppose, as he seems inclined to do, that these deep-sea animals are wholly dependent on the broth concocted at the surface and passing down in a ceaseless rain upon the bottom. Surely no one who has trawled and dredged in the deep sea can have failed to note the large number of free-swimming animals such as Crustacea, Cephalopods, Annelids and fishes of which only an occasional specimen could be caught by the slow moving dredge or trawl, while a faster trawl brought up the more nimble deep-sea types. It seems to us that the results of Chun merely prove that in a close sea, near shore, even at considerable depth there is a great mixture of true deep-sea types and surface pelagic animals which sink at certain times far beyond the limits usually assigned to them. Certainly no one who has engaged in deep-sea work has ever supposed that there were not at the bottom or near the bottom free-swimming animals which occasionally found their way to the surface while many of the so-called surface pelagic types have been proved by deep-sea expeditions to be the young of abyssal species. Chun has however clearly proved that many embryonic stages of surface pelagic animals are only found at considerable depths. Deep-sea fishing with a properly closing net promises to be a material help to embryological investigations.

Chun looks upon the slight changes of temperature as the important factors in determining the periodic rising and sinking of the surface pelagic fauna. He thinks the great increase of temperature at the surface compels surface pelagic animals to seek cooler depths. While this is undoubtedly true for some groups it does not hold good for the larger number and we are more inclined to consider the condition of the surface, whether calm or ruffled by waves and winds, as a more powerful influence. Thus while there is always a richer pelagic fauna to be collected at night it is only on calm nights that a good harvest will be obtained. Yet

in all my experience of surface collecting I have never met with such prodigious masses of surface pelagic animals as on the hottest days of our dredging expeditions. When the sea happened to be smooth as glass under a blazing tropical sun it seemed as if the water was nearly solid as far as the eye could reach with countless surface animals of all sorts. It is true that such remarkable collections were only seen in the track of the Gulf Stream when at a distance from shore, or when we were in the track of currents due to the influence of neighboring islands or continents.

We have a considerable number of deep-sea sedentary types which have an extraordinary bathymetrical range. There is no reason therefore why pelagic animals which are more or less helpless and drift at the mercy of the waves and winds and currents, should not be able to flourish under similar extremes of pressure and temperature. The more so as the majority belong to groups of Invertebrates, on which the effects of pressure would be far less perceptible. The tow-net trawling of Murray in some of the deeper lochs of the western part of Scotland indicates that the range of this deep-sea pelagic fauna does not extend far from the bottom, although specimens of nearly all the species occasionally find their way to the surface. There is nothing to show that the more active deep-sea Crustacea, Fishes, Cephalopods, Pteropods, Annelids, Acalephs, Polyps, Rhizopods have not a considerable range and may pass rapidly either vertically or near the bottom through layers of water of very considerable differences of temperature and pressure. That this movement takes place through all intermediate layers of water near the shores within moderate depths seems conclusively proved by Chun's investigations. That it takes place far from the continental slopes in the oceanic areas is altogether another question. Chun has also come to the conclusion that the surface pelagic fauna does not extend to any great depth, but he has undoubtedly shown that within a short distance from the shore there are a large number of deep-sea pelagic animals living within a moderate range from the bottom, and that they occasionally come to the surface. These deep-sea pelagic types become mixed with the surface pelagic fauna much as many of the abyssal types which have a great bathymetrical range are dredged within the hundred-fathom line or near it, and constitute a part of our shallow-water fauna.

We must remember that nearly all of the Radiolarians which Chun mentions as having been taken with the tow net at a depth of 300 fathoms have also been collected at the surface. The species enumerated of Tomopteris of the Phronimidæ are more common in deeper water than at the surface. The same is true of Stylocheiron, of the species of Spirialis, and of the two species of Cephalopods. But there are several species of large Appendiculariæ, which have thus far escaped the surface tow net of all the naturalists who have explored the Bay of Naples. Chun seems to

have demonstrated for surface pelagic animals a far greater bathymetrical range than they were known to have, and one which, perhaps, corresponds to the wide bathymetrical range of many so-called deep-sea types which extend from the greatest depths at which animals have been dredged almost to the regions of the littoral belt.

An interesting chapter on the "Dissogonie" of Ctenophores concludes this capital memoir. Chun has suggested the term Dissogonie to indicate the peculiar reproduction and development of embryo Ctenophoræ. He has observed that the *Cydippe* form of Bolina, after the degeneration of the genital organs (which are fully developed soon after leaving the egg envelope), is developed into the Bolina form. This monograph is illustrated by five excellent plates from the pencil of Dr. Chun. One of the plates gives a sketch of the deep-sea tow net, as well as of the photographic apparatus used by Dr. Chun. A. AG.

6. *Report on the Annelids, of the Dredging Expedition of the U. S. Coast Survey Steamer "Blake;"* by E. EHLERS. 336 pp., 4to, with 60 plates.—Memoirs of the Mus. Comp. Zool. vol. XV. Cambridge, 1887.—An admirable volume. Some of the plates are colored; all engraved in the best style of the art.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The following is a list of the papers entered to be read at the April meeting of the Academy in Washington:

J. E. OLIVER: The Rotation of the Sun.

T. STERRY HUNT: The Foundations of Chemistry.

T. C. MENDENHALL: On an Improved Form of Quadrant Electrometer, with Remarks upon its use.

E. D. COPE: On the Vertebrate Fauna of the Puerco Series. On the Auditory Bones of the Batrachia.

ORMOND STONE: The Orbit of Hyperion.

B. K. EMERSON: Map of Connecticut River Region in Massachusetts.

A. HYATT: Parallel Series in the Evolution of Cephalopoda. Evolution of Cephalopoda in the Fauna of the Lias.

L. F. WARD: The Evidence of the Fossil Plants as to the Age of the Potomac Formation.

S. P. LANGLEY: Vision and Energy.

H. A. ROWLAND: Report of Progress in Spectrum Photography. Note on the Spectrum of Carbon and its Existence in the Sun.

H. P. BOWDITCH: Reinforcement and Inhibition.

A. GRAHAM BELL: On Apparent Elasticity produced in an Apparatus by the Pressure of the Atmosphere; and the Bearing of the Phenomenon upon the Hypothesis of Potential Energy.

H. A. NEWTON: The Orbits of Aerolites.

E. C. PICKERING: A Large Photographic Telescope.

W. T. SEDGWICK and G. R. TUCKER: A New Method for the Biological Examination of Air; with a description of an Aerobioscope.

WOLCOTT GIBBS and HOBART AMORY HARE: Preliminary Notice of the Object, Methods and Results of a Systematic Study of the Action of Definitely Related Chemical Compounds upon Animals.

IRA REMSEN: On the Constitution of the so-called Double Halogen Salts. Studies on the Rate of Decomposition of the Bromides of the Saturated Alcohol Radicals.

THEO. GILL: The Characteristics of the Order and Sub-orders of Fishes.

F. W. PUTNAM: The Serpent Mound and its Surroundings.

C. V. RILEY: The Systematic Relations of Platypsyllus as determined by the Larva.

C. H. F. PETERS: On the Position of the Nova of 1572, as determined by Tycho Brahe.

J. S. NEWBERRY: Some Notes on the Laramie Group. On the Structure and Relations of Placoderm Fishes.

At the meeting the Draper Astronomical Medal was presented to Professor E. C. Pickering, of Cambridge, and the Lawrence Smith Medal, for original work upon the subject of Meteorites, to Professor H. A. Newton, of New Haven.

The American Anthropologist, published under the auspices of the Anthropological Society of Washington, vol. i, No. 1, January, 1888, 96 pp. 8vo. Washington, D. C., 1888.—This new Quarterly Journal, which has all the commendation it needs in the fact of its being the continuation of the Transactions of the Anthropological Society of Washington, comprises in its editorial Committee: Prof. J. HOWARD GORE, Mr. THOMAS HAMPSON, Mr. H. W. HENSHAW, Prof. O. T. MASON, Dr. WASHINGTON MATTHEWS, S. V. PROUDFIT and Col. F. A. SEELY. It desires to extend the range of its contributions and of the usefulness of the Washington Society. The present number contains papers by Dr. J. C. WELLING on the Law of Malthus; Col. SEELY on the development of time-keeping in Greece and Rome; Dr. FRANK BAKER, anthropological notes on the human hand; and Dr. D. G. BRINTON, on the Chane-abai (four-language) tribe and dialect of Chiapas. Other papers are to appear on the nephrite question, by Dr. A. B. MEYER of Dresden; on the subject "From barbarism to civilization," by Major POWELL; on Discontinuities in Nature's methods, by H. H. BATES of the U. S. Patent Office. The subscription price of the Journal is three dollars a year. Communications should be addressed to Mr. Thomas Hampson, Washington, D. C.

OBITUARY.

OSCAR HARGER, whose death was announced in the December number, was born in Oxford, Conn., January 12, 1843. From his father, a farmer and land surveyor, he inherited great physical endurance, remarkable mathematical talents and the salient points of his strong character. By almost unaided exertions he prepared himself for college, and, entering Yale, maintained himself during the four years of undergraduate study by teaching and mathematical work, and was graduated with high standing in the Class of 1868. During his college course he developed great mathematical capacity and ever after took special delight in abstruse mathematical work, often resorting to it for recreation. It is probable that the bent of his mind was mathematical but, while a boy, he had studied botany and become familiar with the native plants about his home, although his time was so occupied with farm labor during the proper time for botanizing that he commenced the study of grasses and sedges in winter, collecting and identifying many species from the hay stored in barns. His success in botany undoubtedly led him to turn his attention to other departments of natural history, and after graduation from college he abandoned the mathematical career open to him and began the study of zoology with Professor Verrill. In his

zoological studies he at once showed special aptitude for original work and had begun important investigations when, in 1870, he accepted the position of Assistant in Paleontology under Professor Marsh, which he held uninterruptedly until his death.

Although the greater part of his time and energy was given to work in vertebrate paleontology, he continued his investigations in invertebrate zoology as long as his health permitted and published papers on myriapods, a fossil arachnid, isopods, and, jointly with the present writer, a report on a dredging expedition to the region of St. George's Banks. His last and most important published works are a report on the Marine Isopoda of New England and the adjacent waters, and on the Isopoda of the Blake dredgings on the eastern coast of the United States. The former, his only completed work, is a systematic and accurate monograph, one of the most important contributions to our knowledge of the Isopoda, and will long remain a standard authority and a manual for the study of that group on our coast.

These publications establish his reputation as a zoologist, but his best work and highest attainments were in the department of vertebrate paleontology. Remarkable logical powers, an unbiased mind, and years of accurate observation, had given him a truly wonderful knowledge of vertebrate osteology. Under his hand the broken and disarranged bones of an unknown carpus or tarsus seemed to fall into their proper places by magic. But his knowledge was not one of details alone; he had a truly philosophical grasp of the bearing of facts on evolution and classification; and only the few who knew his attainments can appreciate how much paleontological science would have been advanced had he been able to publish his observations and conclusions. He was not a scientific specialist only, but took a deep and practical interest in politics and other questions of the day, and his peculiarly open mind, wholly untrammeled by bias or preconception, gave his views and arguments on any subject originality and value.

Mr. Harger never enjoyed robust health, and in 1879 he was attacked by a cardiac trouble which increased from year to year. Though knowing that his life was despaired of by his physicians and friends, he never spoke of his illness but, with silent courage and indomitable will, worked on cheerfully, attending to his regular duties until prostrated by cerebral hemorrhage a week before his death.

In 1875 he married Miss Jessie Craig of New Haven, who, in the highest sense, was his helpful and sympathizing companion. Only those can fully appreciate his loss whose privilege it was to belong to the little circle enjoying his every day companionship and who feel that they are better for the example of his pure and inflexibly truthful life. S. I. S.

Professor Jules-Émile Planchon, of Montpellier, died April 1st, at the age of 65 years.

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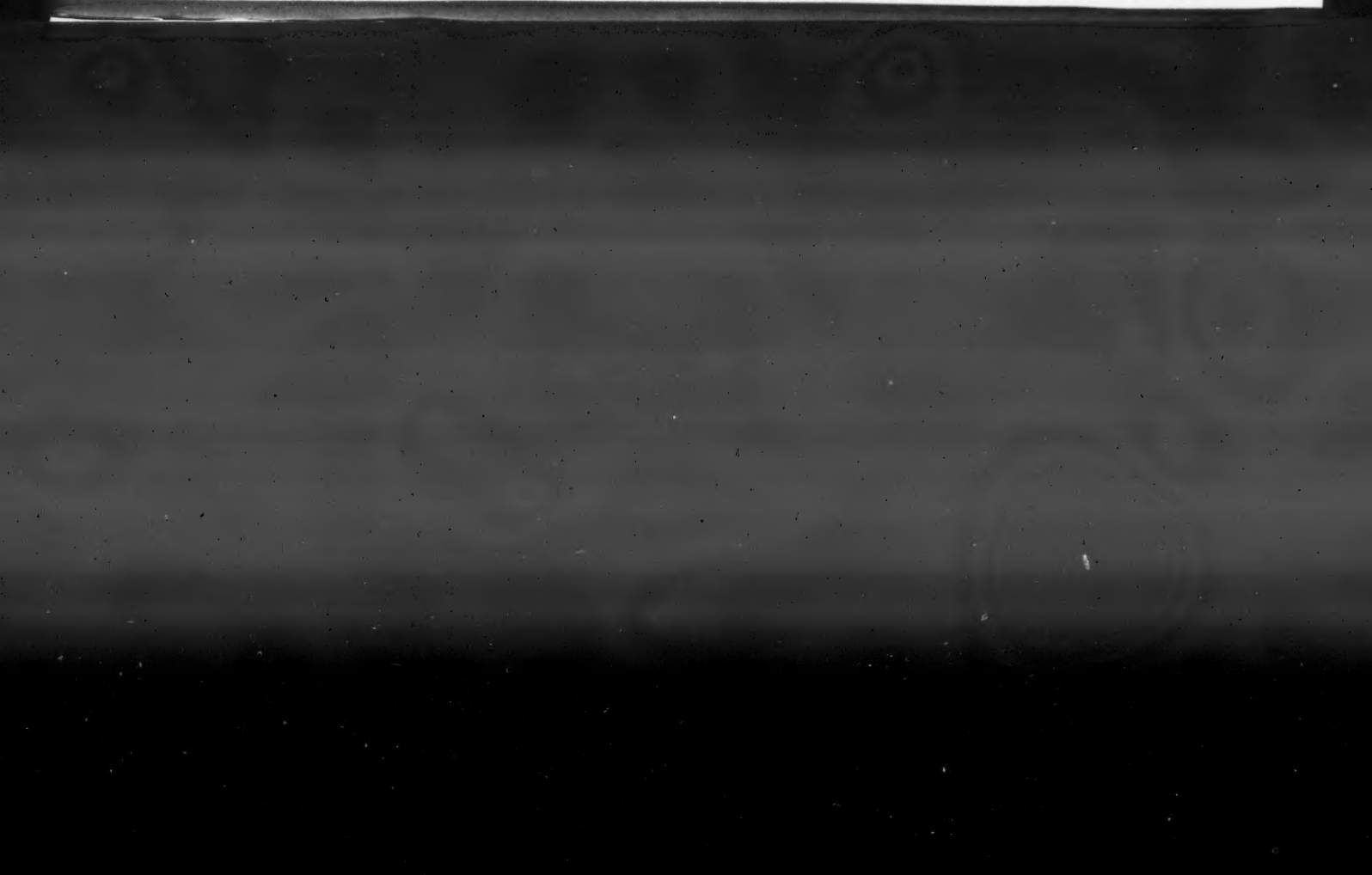

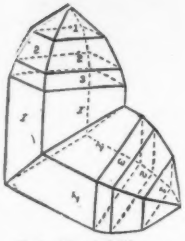

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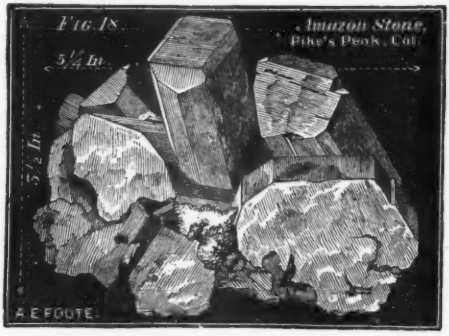

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